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A Canadian Dynamic Controlled-Climate Test Facility

Feasibility Study Final Report

Prepared for the Transportation Development Centre
Transport Canada

by DSMA International Inc.
Toronto, Canada

February 1983

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The contents of this report represent the opinions and judgement of the Consultants, and do not necessarily reflect the official views or policies of Transport Canada.

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17. Abstract

A three-phase feasibility study has been carried out for the creation of a new dynamic (airflow simulation) controlled-climate test facility in Canada. The facility would be used for research, development and testing of rail vehicles and other large equipment under controlled climate extremes (temperature, humidity, freezing rain, solar radiation, etc.).

During the first phase of the study, approximately 150 potential Canadian users of the facility were canvassed regarding level of interest and preferred test configurations and capabilities. Candidate users in the government, industrial and academic communities were polled. Detailed follow-up interviews were held with approximately forty respondents.

The second phase of the study developed conceptual engineering designs of the proposed facility for three levels of testing capability. All designs centered on the creation of the facility as an add-on to the new National Research Council static cold room, and in accordance with information received during the survey phase.

The final phase of the study developed operational scenarios for the recommended facility concepts, and used these as the basis for a staged benefit/cost assessment. The study concludes with recommendations on the conceptual design and configuration of the facility, its location, and management/staffing. Projections of capital acquisition costs and operating costs are made. Recommendations are also made for marketing and design study activities for the facility.

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17. Abstract

Une étude de faisabilité en 3 phases a été menée concernant la construction au Canada d'une soufflerie aérodynamique à climat contrôlé, pour la recherche, le développement et l'essai de véhicules ferroviaires et de matériels lourds dans des conditions climatiques rigoureuses contrôlées (température, humidité, verglas, rayonnement solaire, etc.).

La première phase de l'étude a consisté à faire un sondage auprès de quelque 150 utilisateurs possibles de la soufflerie envisagée, pour connaître leur réaction à cette idée, déterminer les utilisations qu'ils envisagent et évaluer l'ampleur de la demande pour ce type d'installation. Les milieux sondés ont été choisis au niveau du gouvernement, de l'industrie et des universités, et une quarantaine d'interviews personnelles ont été faites.

La deuxième phase a eu pour objectif d'élaborer des concepts portant sur trois schémas de réalisation distincts, mais tous axés sur l'idée d'adjoindre la soufflerie à l'installation d'essais climatiques statiques du Conseil national de recherches, et prenant en compte les résultats du sondage fait au préalable.

La troisième phase a permis d'élaborer divers scénarios d'exploitation applicables aux concepts retenus, et qui ont servi à jeter les bases d'une étude du rapport avantages-coût. L'étude conclut en proposant divers concepts et schémas de réalisation du projet, l'emplacement à retenir, ainsi que le mode de gestion et de dotation en personnel à adopter. Elle assortit chaque proposition d'un devis estimatif quant au coût de premier établissement et d'exploitation. Efin, des recommandations sont faites concernant les études techniques et la promotion de l'installation.

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Intempéries	Ecoulement de l'air	Température	
Pluie	Aérodynamique	Soufflerie	
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Finally, the efforts of DSMA Atcon Ltd. (D. Ferguson and W. Corke) in their role as sub-consultants during the user survey are acknowledged.

FOREWORD

This is the final report of the Transportation Development Centre Controlled-Climate Test Facility Study. The study, commencing in June 1981, was conducted for the Transportation Development Centre (TDC) of Transport Canada under Department of Supply and Services Contract Serial No. OSD81-00023.

The study was carried out by the consulting engineering firm of DSMA International Inc. (DSMA). The Consultants have had extensive experience in the design, construction and operation of climatic test facilities and wind tunnels, not only in Canada, but also in Europe and the United States. Major DSMA-designed climatic facilities are now in operation for such firms as Volvo, Chrysler, BL Cars, Ford (Germany), AMOCO and Esso (UK).

The study findings are presented in two reports. This main report contains a description of the study methodology, analysis, results and recommendations. The supplementary report is a separately-bound compilation of the information gathered by DSMA International during the initial user survey phase. Issued as Transport Development Centre (TDC) Report No. TP 3971, "Canadian Dynamic Controlled-Climate Test Facility Study: User Survey Interview Summaries", it contains detailed results of the prescreening questionnaire, along with summaries of the follow-up interviews which were conducted. Information gained during the questionnaire and interview processes was considered confidential by some respondents and has therefore been bound separately in that supplementary report and made subject to restricted circulation.

SUMMARY

A three-phase feasibility study has been carried out for the creation of a new Canadian dynamic controlled-climate test facility (climatic wind tunnel) for research and development of large vehicles and equipment. The three phases consist of:

1) User Survey
2) Conceptual Design
3) Benefit/Cost Analysis

The user survey solicited interest via Telex questionnaire from 141 Canadian corporations, ten federal government departments, and 22 Canadian universities/colleges, followed by detailed interviews with 30 of the most promising corporate contacts and eight of the government contacts. Significant interest was found in climatic effects with regard to product development, although the Consultants believe that at least 90% of the controlled facility test usage which could be generated by this interest is best served by a large static cold chamber (that is, without airflow simulation). This requirement was met during the study by the announcement of the National Research Council's new Climatic Engineering Facility at the Railway Laboratory near Ottawa (commissioning date in May 1983).

Nevertheless, the user survey has determined considerable interest in dynamic-airflow, controlled-climate testing of large equipment from a limited but important group of corporations, along with research and development concerns on behalf of the the Department of National Defence, the National Research Council, and Transport Canada. Although projected test usage of the proposed facility is low for its first years of existence, the Consultants have identified a strong probability of 'copy-cat' testing coming into play, should the facility be made available. Many potential corporate test clients have climatic concerns, but are unable to articulate or project these into facility usage rates, due to their unfamiliarity with dynamic controlled-climate test concepts and capabilities.

Conceptual designs, with capital acquisition and operating costs, have been developed during the study for three levels of dynamic testing capability. All are proposed on the basis of a phased development of the new NRC Climatic Engineering Facility in order to capitalize on existing test staff and reputation, while sharing site acquisition and development costs.

Capital acquisition costs for the three levels of test capability range from $17.6 million to $20.7 million (estimated to ±20% accuracy in October 1982 Canadian dollars). The highest-capability facility is recommended in order to capture maximum return on investment. Test capability would permit investigations to be carried out on machinery up to and including the size of rail locomotives, for windspeeds of up to 100 km/h and temperatures from +50°C to -30°C. Provision of test temperatures below -30°C is not recommended due to extreme cost penalties for capital construction and operation. Special test systems will permit studies of high humidity, rain and freezing rain, and solar heating, plus chassis dynamometer studies for wheeled vehicles (excluding rail vehicles) of up to 375 kW engine power with a wide range of drive axle arrangements.

The Consultants recommend that the conceptual design elements of this report be used by Transport Canada as the focal point for a new phase of discussions with selected sectors of Canadian industry. By illustrating in definitive fashion a range of proposed testing capabilities, it is expected that considerably greater interest in dynamic controlled-climate testing will be identified amongst Canadian (and United States) corporations. This will in turn lead to a closer definition of facility requirements appropriate to the undertaking of a preliminary engineering phase.

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1. INTRODUCTION

1.1 General

This report is arranged according to the logical order of phases in which the study was conducted. These consist of the user survey, the facility conceptual design, and the benefit/cost analysis. A brief summary of the background and rationale leading to this study follows:

1.2 Study Background

The Transportation Development Centre (TDC) of Transport Canada has sponsored this study into the feasibility of developing a dynamic (i.e. simulated airflow) controlled-climate test facility. TDC support research and development activities aimed at improving rail transportation. One area of interest to both manufacturers and operators is the effect of varied climatic conditions on operational safety, crew and passenger comfort, and equipment reliability, and performance.

In a country which possesses both a vast rail network and a broad range of climates, Canadian railways in particular (and Canadian industry in general) are concerned about the impact of varied and frequently adverse climatic conditions on the performance of their products. As if the Canadian climate were not enough, Canadian manufacturers must compete in world export markets as well.

At the moment, there is no test facility in North America which is capable of testing complete rail cars or locomotives under dynamic conditions. The only facility which is even remotely accessible is the Vienna Arsenal Vehicle Testing Station located in Vienna, Austria. There is a static test facility which is occasionally used for rail vehicle testing in North America, but it is owned and operated by U.S. rail car manufacturer (the Budd Company). There is an obvious reluctance on the part of other manufacturers, including Canadian companies, to perform sensitive work in that facility.

The Vienna example of a dynamic test facility is considered essential by European operators and manufacturers (References 1-7). The Vienna Arsenal facility was built in 1959-60 and upgraded in 1973-74. It has the claimed capability of simulating vehicle

aerodynamics for speeds of up to 250 km/h. Vienna Arsenal are supported by the International Union of Railways and receive particularly strong support from the German Federal Railway and the French National Railways.

Transport Canada have been approached by Canadian manufacturers of railway equipment expressing the need for a controlled-climate test facility (CCTF). They have been concerned by a trend on the part of equipment purchasers towards specification of controlled-climate testing in new vehicle purchase contracts. These specifications increasingly apply in the U.S. export market.

This study has been implemented by TDC to examine and assess the viability of a controlled-climate test facility, within the context of the Railway Advisory Committee Research Programme.

The project feasibility study was structured in two phases. In the first phase, the Canalog division of CANAC Consultants Ltd. assembled the railway sector's perspective on their controlled- climate test needs (Reference 8). In this second phase of the project, an assessment of the needs of the transportation industry as a whole is to be compiled as part of a determination of the ability of such a facility to meet the needs of other users. In addition, the study also attempts to examine non-transportation industries which might contribute to the total utilization of a dynamic facility.

The Canalog study involved discussions with North American and European railway officials concerning the value to the railway industry of a controlled-climate test facility. The study included visits to the Vienna and the Budd Company facilities. The study concluded that the Canadian railway industry displayed a cautious interest in a static facility and, with a few notable exceptions, very little interest in a dynamic facility.

This second phase of the project encompasses an overall assessment of current and projected controlled-climate testing needs which could be satisfied by a new large-scale testing facility. The study includes analysis of the testing "market", the facility concept definition, costing, location, management, and a cost/benefit analysis. Thus the study provides the basis for detailed consideration of the viability of a dynamic controlled-climate test facility in Canada.

2. USER SURVEY

2.1 General Approach

The user survey was designed to try to answer the following question:

> If a large-scale climatic test facility were made available, what use would be made of it by Canadian industry, government and academic institutions?

At the outset, it was apparent (particularly from the results of the preceding Canalog study) that it would be very difficult to obtain an objective answer from most organizations, public or private. The major difficulty lies in the fact that relatively few organizations have the personnel and testing experience to be able to visualize the possibilities open to them with such a facility. Asking the question directly would not help in identifying the latent demand which can only emerge when designers, test engineers and researchers understand a technology and can appreciate its relevance to their particular design problem.

The only apparent approach to dealing with this problem was to first explain the potential capabilities of such a test facility in some detail. With this background, engineers and researchers could then speculate on how the facility might be of use in their particular activities. It was evident that useful information would only emerge from detailed interviews conducted by technically knowledgeable interviewers.

Given the time and cost constraints imposed on the study, it was not feasible to conduct the large number of face-to-face interviews necessary to achieve adequate coverage of the relevant Canadian markets. This led to the design of a survey methodology whose major objective was to screen a large number of organizations and isolate the relative few who met the following criteria:

1. Organizations which manufacture or operate large mechanical or electrical equipment for outdoor use.

2. Organizations which are concerned about the effects of climatic conditions on their activities or products.

3. Organizations which have an interest in climatic testing and research.

The resulting survey methodology is depicted in Figure 1 and consists of a market classification followed by a series of pre-screening questionnaires to establish likely candidates for detailed follow-up.

The market classification was carried out intuitively. Federal government agencies were chosen for relatively intensive coverage based on an initial perception on the part of the Consultants that a significant part of the climatic research and development currently taking place was supported in whole or in part by government funding. Government agencies were thus expected to have an effective overview of potential research topics. This group is discussed in Section 2.2 and listed in Table AI-1 of Appendix I.

The University classification was identified as a further source of ideas concerning possible research or testing projects. Due to the uncertainty of funding availability for academic research projects, it was not expected that the universities would be able to furnish estimates of potential facility usage. Accordingly, the universities were segregated to allow for a less intensive survey procedure. This group is discussed in Section 2.3 and listed in Table AI-3 of Appendix I.

The final market classification included all Canadian private sector industrial and operating organizations. It was in this group that a wide variety of interest and expertise was expected. Accordingly, the survey methodology called for a sequential screening process to try to achieve both relatively wide coverage and efficient identification of those organizations for whom the dynamic controlled-climate test facility might have relevance.

The screening process for the industrial sector began with a further classification of the industries which might have use for the facility under study. These industries are listed on Table 1 and are characterized by their production or use of large-scale mechanical and electrical equipment. The organizations approached were identified by reference to industrial directories. A detailed discussion of the industry survey appears in Section 2.4. A list of contacts appears in Table AI-2 of Appendix I.

2.2 Canadian Government Agencies

The task of canvassing Canadian federal government agencies was carried out primarily through the medium of direct interviews. It was felt that the Transportation Development Centre, together with the representatives of other ministries and departments who formed the Steering Committee, could identify the interested parties in government. Based on their suggestions, the following organizations were approached:

National Research Council

Department of National Defence
- Land Engineering Test Establishment (LETE)
- Defence and Civil Institute of Environmental Medicine (DCIEM)

Transport Canada
- Motor Vehicle Test Centre, Blainville, Quebec

Energy, Mines and Resources Canada

Environment Canada

Industry, Trade and Commerce

National Energy Board

A number of possible uses for a dynamic controlled-climate test facility were identified by the various organizations. Of these uses, most were speculative in nature and have been included in the list in Section 2.5.1. There were, however, two organizations whose level of interest and knowledge of the potential facility were sufficiently well defined that they deserve separate discussion. These two organizations were the National Research Council (NRC) and the Land Engineering Test Establishment (LETE).

2.2.1 NRC Comments

The National Research Council support two major research sections which have particular relevance to this study. The first entity is the Low Temperature Laboratory (LTL), headed by Mr. T. R. Ringer.

He is widely acknowledged as the leading Canadian expert in low temperature testing. The second organization is the Railway Laboratory, headed by Mr. C. A. M. Smith. The LTL is located at NRC's Montreal Road campus in Ottawa, while the Railway Laboratory is a relatively new facility located near Ottawa's Uplands Airport.

The LTL facilities consist of a variety of installations:

1. Large Static Cold Chamber
2. Low-Speed Icing Tunnel
3. High-Speed Icing Tunnel
4. Outdoor Snow Ingestion Facility
5. Small cold chamber at Western Laboratory (Vancouver)

The existing Large Static Cold Chamber is 30 years old and is being replaced by a new static facility. Construction of this facility by NRC-LTL at the Railway Laboratory site has been completed. The new Climatic Engineering Facility, as it is called, has the following features:

1. Test section dimensions: 30.5 m(L) by 6.1 m(W) by 6.1 m(H)

2. Capability of splitting test section into 15.2 m, 9.1 m, and 6.1 m lengths (or combinations thereof), with independent temperature controls

3. Temperature range of -50°C to + 50°C

4. Fully automatic refrigeration systems (capable of unattended operation)

5. Heavy, concrete-slab floor with embedded railroad tracks capable of supporting a 270-tonne locomotive

6. Spurline access from mainline railway

7. Estimated cost of $2 Million with commissioning in May 1983.

This facility clearly indicates NRC's commitment to research into large-scale, low-temperature phenomena. The facility also meets most of the requirements defined in the terms of reference for this study. With the major exception of its inability to conduct dynamic

testing, the new NRC Climatic Engineering Facility (CEF) will be able to investigate cold climate performance of very large railway vehicles and other equipment of similar size.

NRC's activity with the new CEF stands as a clear model for the possible operation of any large-scale climatic test facility. Their client base, utilization rates and operating practices are very relevant to any attempt to predict the nature and scope of possible testing activities in the facility under study.

The CEF will probably continue the activities which the NRC-LTL has carried out in the past. In characterizing NRC's climate testing activities, Mr. Ringer said that although some of the work is initiated internally, most results from external requests. NRC have clients in both the industrial community and in the military. He described almost all their work as "mission- oriented applied research".

In terms of the distribution of activity, Mr. Ringer suggested that about 60% of NRC's climatic test work is research and development, while the remaining 20% is performance testing. Of the research and development, the bulk is related to developing and verifying performance standards, while a small but growing proportion is devoted to product development.

Mr. Ringer felt that a dynamic CCTF in Canada will not be able to contribute very much to the performance specification development work carried out by NRC. He cited the lack of comparable facilities worldwide, noting that even if standards were developed there would be nowhere except the CCTF in which to carry out compliance testing. This implies that facility usage by NRC would have to be focussed primarily on product development.

NRC-LTL's work in product development arises from a relatively recent Council-wide Programme for Industry/Laboratory Projects (PILP). PILP involves a transfer of technology from NRC to private industry, with an emphasis on development work rather than on research. NRC-LTL have completed two such projects in the last five years, the major one involving an icing detector for helicopters. NRC lent assistance to the industrial firm developing the unit throughout the research, development, pre-production and qualification testing phases.

The experience of NRC-LTL in climatic testing indicates that a significant proportion of the usage of a dynamic CCTF would be generated either directly or with the involvement of NRC. While Mr. Ringer did not have a specific project in mind, he indicated a number of areas where the capabilities inherent in a large-scale dynamic facility could be of benefit to Canadian researchers and engineers. These speculative ideas are listed along with those of other organizations in Section 2.5.1.

Mr. Ringer added a final comment based on his experience in providing cold temperature testing facilities to Canadian industry. He felt that industrial users were unlikely, in the near future, to be willing to pay more than $3,000. to $4,000. per day to use any climatic test facility. Even at these rates, he did not foresee more than three months usage of a dynamic CCTF in any given year.

In summary, it appears likely that, because of their experience with cold climate testing and their active involvement in ongoing research, NRC will continue to have an active role in climatic testing. Moreover, the new CEF will serve many of the same users as a dynamic CCTF. A summary of NRC comments appears in Appendix III.

2.2.2 LETE Comments

Discussions were held with representatives of the Land Engineering Test Establishment (LETE) of the Department of National Defence. LETE is the organization which performs testing on land-based military equipment. Most of their work is mission-oriented, with an emphasis on compliance testing and problem solving. LETE do not perform basic research and seldom do standards development.

LETE have often relied on NRC for its past testing programmes and generally find that the Ottawa location of NRC allows for simple logistics. LETE have concentrated on land vehicle testing and would like to be able to conduct cold starting, performance tests, icing studies, rain simulation and simulation of road load. Temperatures between -40°C and +40°C would be satisfactory.

LETE indicated that they would be very interested in testing vehicles under airflow simulation, especially if a dynamometer were present. Air speeds need not be great since most vehicles would not exceed 65 km/h. The dynamometer would have to accommodate at least

a four-wheel-drive vehicle and perhaps even tracked vehicles. Nonetheless, it was indicated that there were many tests which do not require a dynamic facility and that the capability, while desirable, was not essential. LETE indicated that the new NRC Climatic Engineering Facility would fulfill their essential testing needs.

Many of LETE's desired testing capabilities are similar to those of other vehicle manufacturers and are listed under Section 2.5.1. There were a couple of specialized requirements related to testing such items as the new Leopard tank:

1. Icing of vision ports and periscopes is a potential concern which might require a dynamic facility.

2. Heat output of 300 kW for cold start and 625 kW for full power would tax most facilities' refrigeration systems

The expected facility usage would be approximately 40 days per year for a facility equal to or better than the NRC CEF. Past usage has averaged twenty days per year.

Overall, LETE's relatively unusual requirements would place substantial testing demands on a facility. While there is a significant interest in possibilities for dynamic testing, LETE could perform a lot of productive development work without it. If a dynamic test facility were available, LETE would prefer that it be in Ottawa and be operated by NRC, with whom they have developed a good working relationship. See Appendix III for detailed summary.

2.3 Canadian Universities

The university survey was carried out by mail. A letter was sent to the heads of engineering departments at twenty-two Canadian universites. The letter included a brief explanation of the purpose of the survey and a prescreening questionnaire similar to the one sent to Canadian industrial organizations. It was hoped that research projects would be reported which might be able to benefit from the facility under study.

In all, fourteen responses were received from researchers in the universities. These responses indicated that work on climatic testing is taking place in several universities, but on a relatively

modest scale. Little direct interest was shown in the capabilities for large-scale dynamic climatic simulation, although several researchers did speculate on possible future research topics which might be relevant. Those ideas which were presented for possible uses of the facility are included in the summary list in Section 2.5.1.

The lack of definitive response from the universities is likely due to the novelty of the possibilities offered by the facility under study. Most of the on-going research described in the responses centred on small-scale testing which is currently more appropriate to the universities' available test facilities and budgets.

Based on the discouraging results obtained from the letter survey, a decision was made to refrain from conducting personal interviews in the universities in favour of spending more time and effort among industrial organizations.

2.4 Canadian Industry

The industrial survey was carried out in three stages. These stages were designed to progressively screen the companies contacted in order to ensure that only those with relevant experience or interest were subject to requests for direct interviews. In addition to reducing paper burden in a government study, this method permitted concentrating knowledgable interviewers on those organizations which were most likely to have a strong interest in participating. The three stages of the industry survey were as follows:

1. Prescreening Questionnaire - A one-page questionnaire was sent by Telex to 140 Canadian companies. The companies were identified by reference to industrial directories and were chosen based on their production or use of large-scale mechanical or electrical equipment in outdoor applications.

2. Followup Letter - Where the results of the prescreening questionnaire indicated interest or activity in climatic testing on the part of an organization, the next step was to arrange a direct interview. In order to prepare for the interview, the Consultants first sent a letter which contained a detailed list of the topics they wished to discuss.

3. Direct Interview - The final step was to arrange a face-to-face interview which addressed the topics defined in the followup letter. Apart from the agenda provided in the followup letter, the interviews were allowed to be free-flowing discussions. The interviewers tried to encourage informed speculation about possible utilization of a dynamic controlled-climate test facility. As a result, these interviews addressed a number of subjective issues in addition to technical concerns.

Overall, 140 prescreening questionnaires were sent out to Canadian industrial organizations. From these contacts, 93 responses were received for a response rate of 66%. This very satisfactory response rate was probably due to the choice of Telex as a means of distribution. The Telex medium, especially when used in conjunction with the Store-and-Forward Telex (SAFT) feature (which permits the same text to be sent to a large number of addresses) is a very reliable and convenient way to communicate with industry. In addition, the Telex may command a higher degree of attention than a letter.

Based on the responses to the prescreening questionnaire, followup letters were sent to 46 organizations. Telephone contacts were then made with the organizations in order to schedule meetings. During the telephone conversations, several companies indicated disinterest in continuing the discussion. Ultimately, 30 companies or operating organizations participated in direct interviews. The results of these interviews are given in Section 2.4.2.

Overall, the industry survey process went smoothly and generated a number of interested responses. In particular, the survey methodology allowed relatively efficient identification of the companies which were interested in the capabilities of the dynamic controlled-climate test facility. Copies of all the relevant forms and letters, including the questionnaire, appear in Appendix II.

2.4.1 Market Overview

The results of the industrial market survey were interesting but ambiguous. As was expected, the level of activity and interest displayed by Canadian companies varied dramatically from firm to firm. Nonetheless, there was a consistent indication that climatic design and operational concerns are widely felt in the industrial

sectors which were studied. Table 1 shows the general response to the various questions on the prescreening questionnaire. Of the 93 responses which were received, 83 (89%) agreed with the statement that climatic conditions affected their design or operations. Of the 83 who agreed, 73 (88%) said that they engaged in climatic research and development at least occasionally.

In all, therefore, 78% of the companies who responded are active in some form of climatic testing. Over half of these companies carry out testing in their own facilities, further underscoring the importance of this type of testing. Even if the extreme assumption were made that all the companies who failed to respond did so because of their lack of interest in climatic research and development, the survey would still indicate that over 50% of the 140 companies who were approached are concerned enough about climatic testing that they engage in it to some degree.

While the overall response pattern indicated strong industry interest in climatic research and development, there were some differences between industry groups. Reference to Table 1 indicates that the greatest level of response was obtained from the railway, electrical, aerospace and off-highway vehicle sectors. These groups also exhibited a strong concern for the effects of climatic conditions on their equipment. A lower response was received from the road transport sector, but those who did respond were interested in climatic effects.

The interest shown by these groups led to a concentration on these sectors during the subsequent interview process. Table 1 also shows the distribution of actual interviews by sector. Over 40 companies were approached and the distribution of resulting interviews was affected to some degree by the level of interest shown by specific firms and by the constraints of logistics. Nonetheless, the interviews were reasonably well distributed to provide a good cross section of opinion.

While the prescreening phase served to identify the organizations which were priority targets for interviews, the remaining questions on the questionnaire produced inconclusive results. General observations can be made about the distribution of responses as depicted in Figures 2 through 9.

1. The greatest concern for the impacts of climatic effects were in the areas of mechanical failures, reduced performance and design setting adjustments. Operator efficiency was a consideration but was not felt to be as important as the others.

2. Over 60% of those who indicated concern for climatic effects perform at least some of their tests in their own facilities. In most cases this would imply relatively small-scale tests or component tests, since large-scale test facilities are uncommon.

3. Almost 60% portion of companies rely to some extent on field tests to determine climatic effects.

4. A smaller proportion (35%) make some use of government test facilities.

5. The large majority of positive respondents are located in Southern Ontario and the Montreal/Ottawa region.

There was nothing in the answers to the prescreening questionnaire which was particularly unexpected. There is a widely felt awareness of climatic effects as an area of concern, and companies seem to be dealing with it in their own manner. Most of the specific information which was gathered during the industrial survey was obtained during the technical interviews which are described in the following section.

2.4.2 Interview Responses

To a large extent, the most productive phase of the user survey process occurred when technical interviews were conducted with interested industrial organizations. It was during this activity that it was possible to probe industry attitudes toward climatic testing and toward the potential utilization of a dynamic controlled-climate test facility.

All of the participants were promised confidentiality with respect to company-specific technical information. With certain exceptions, therefore, details cannot be cited in this report. Nonetheless, the interview responses produced several common concerns or ideas.

Technical Considerations

The companies surveyed desired a wide range of technical capabilities in the dynamic controlled-climate test facility:

1. Extreme temperature requirements varied from -55°C to +80°C. Most companies, however, were interested in the range from -40°C to +50°C.

2. Interest in airflow simulation was restricted to firms in the railway, road transport, off-highway and electrical industries. Altogether, only about 20% of the firms were interested in any degree of airflow simulation. At the same time, the staff interviewed at many of the companies had little or no experience with dynamic testing and were hesitant to make any judgements.

3. Despite the lack of interest in dynamic testing per se, well over half of the firms interviewed expressed interest in simulation of such environmental phenomena as rain, freezing rain, snow and sand or dust. Several of these require at least some level of airflow simulation.

4. Approximately 20% of those interviewed were interested in humidity simulation during testing.

5. The firms in the railway sector were the only ones concerned about rail access. Their concern was strongly felt, however, since there is no other way of practically transporting a rail vehicle.

Commercial and Financial Considerations

1. Several manufacturers were not eager to endorse the development of a facility for controlled-climate testing because they are not presently obligated to perform climatic testing. Several were afraid that the existence of a test facility would encourage equipment purchasers to demand compliance testing when ordering equipment. Those manufacturers who were supportive of the concept were either already committed to testing or were seeking a way to comply with specification requirements they anticipated were forthcoming.

2. Several operating authorities, on the other hand, were interested in climatic testing, but wanted their suppliers to perform it.

3. Most organizations wanted the test facility to be located close by. The costs of transporting a test object and the associated test personnel to a distant location was considered to be a major deterrent to frequent facility use.

4. Virtually all of the organizations interviewed were extremely cost-conscious. It was very difficult to discuss possible testing fees without the discussions taking on the trappings of a negotiation. While some organizations were willing to speculate as to the level of use they would make of the facility, their estimate was always accompanied by caveats about cost and accessibility.

5. Several of the firms interviewed were noncommittal due to their status as subsidiaries of foreign parents. At least five of the firms indicated that they would have to clear usage of the facility with their parent's research division.

6. None of the companies contacted (apart from Bombardier, which will be discussed in more detail in the next section) were willing to commit to using a controlled-climate test facility for more than twenty to thirty days in any one year, and most of those could not guarantee that their usage would be consistent from year to year. Several companies anticipated doing climatic testing only when they introduce a new product.

While most of the comments presented above are subjective, there were two organizations whose comments are sufficiently well defined that they deserve separate discussion. Bombardier Inc. are the most enthusiastic of the Canadian rail equipment manufacturers with respect to climatic testing. They have conducted controlled climatic tests on the new LRC passenger rail car and, together with VIA Rail, are committed as a matter of policy to further testing on all new products.

Their evident interest in using a large-scale dynamic controlled-climate test facility was noted in the Canalog study and forms part of the background to this study. Accordingly, the comments

of Bombardier and VIA have been summarized separately in the following sections (they appear in detail in Appendix III).

A. Bombardier Inc.

Bombardier Inc. have the distinction of being the most active Canadian rail vehicle manufacturer, with respect to climatic testing of its products. On two occasions, Bombardier have taken rail passenger cars (e.g. the new LRC) to Philadelphia for climatic testing in the cold chamber of its U.S. competitor, the Budd Company. The evident drawbacks of this arrangement have contributed to Bombardier's enthusiasm for a Canadian CCTF.

Bombardier's concerns regarding environmental testing are divided into two major categories: locomotives and passenger rail cars. Bombardier are very positive about the values of climatic testing for a variety of reasons:

1. Bombardier perform all of the product design and development for their rail passenger cars in response to the customer's requirements. As a result, Bombardier do not evolve a product; rather they change their technology and approach on a contract-by-contract basis. It is thus company policy to perform climatic tests on prototypes as early in the product development cycle as it can manage.

2. Concerns with environmental design of passenger cars centre on design with new materials applications, passenger comfort and locomotive power consumption.

   a. As new materials are increasingly used in rail vehicles, their thermal characteristics interact in new and sometimes unexpected ways.

   b. Insulation design and selection is a tradeoff between vehicle weight and concerns for passenger comfort and the reliability of onboard systems. Water systems, for example, may be vulnerable to freezing since there is a lot of piping in a typical vehicle and complete protection is often difficult due to restricted space.

c. Passenger train length is typically limited more by the ability of the locomotive's auxiliary power unit to supply passenger car operating needs (e.g. heating, cooling and electricity) than by the tractive power available. The current practical limit is ten cars per train.

3. Concerns with climatic design of locomotives are not as urgently felt as they are with passenger cars, but nonetheless there are areas which bear investigation:

   a. The evolutionary nature of railway standards is a major reason for the previous lack of interest in climatic testing. Concern for climatic performance is increasing, however, and it was felt that testing may become a more important practice if facilities are available.

   b. Climatic design issues which have been identified in relation to locomotive design include snow ingestion in air inlets, noise generation by air handling systems, and wind-wipe problems with combustion air inlets.

Bombardier's requirements for a climatic test facility are based on the types of concerns outlined above. Many of their requirements are not related to the technical characteristics of the facility, but rather are related to the operation and support which is available. Bombardier's comments are particularly valuable in this respect because of their experience in using a contract facility at Budd. Some of their requirements are as follows:

- easy access for power cables and availability of a large DC power supply
- data acquisition and reduction system
- capability of accepting different wheel gauges
- good thermal insulation
- specialist group in charge
- location in Eastern Canada
- solar heat loading
- all information gained should have restricted access
- snow and ice simulation (if feasible)

The requirements point to the importance of the support and test personnel available at the test facility.

Bombardier indicated that they would use a suitable test facility for at least two vehicles in each of the next two years. Since each test would take approximately one month, this would result in two months of testing per year. Future utilization will depend on the number of new designs which Bombardier will introduce.

As an indication of the costs which Bombardier have been bearing during use of the Budd facility, they have spent approximately $75,000 for test facility usage alone during each of the two three-week tests they have conducted there. In addition, they have incurred significant costs for transportation, staff time, and travel expenses.

Overall, Bombardier have a strong and active interest in dynamic fixed-facility climatic testing. This interest, plus their previous experience in similar testing, identifies them as one of the most likely candidates for utilization of the dynamic facility. In addition, Bombardier have a strong interest in the airflow simulation which is only available in a dynamic facility.

B. VIA Rail

In many ways, comments from VIA Rail are identical to those from Bombardier. VIA's involvement in the LRC programme has given the two organizations a common background in fixed-facility climatic testing. VIA feel that railway vehicles should be tested by the equipment supplier in the first instance, but VIA have only one maintenance facility and little redundancy, so reliability is a major requirement. VIA felt that more research and or testing is required in railway vehicle design and operation.

The criteria which VIA would use in evaluating a potential test facility were listed as follows:

1. Good accessibility
2. Reasonable availability - VIA can live with two to three month lead time for testing
3. Good data reduction capability
4. Acceptable user fees (not defined)

In addition, the VIA spokesman indicated some criteria which should be used to evaluate any new facility which might be developed by the Canadian government:

1. The facility should aim to decrease the fragmentation of testing in the railway industry

2. The facility should not involve an entirely new organization (operation under NRC would be ideal)

3. The railway industry is doing about half the climatic testing that it should. The facility should encourage more testing to be done.

4. The facility should be designed for the capability of carrying out compliance testing

VIA Rail felt strongly enough about the need for climatic testing that they would be prepared in principle to go on a retainer basis for six weeks of test facility time per year. There was no willingness however, to commit to a price for such usage.

VIA Rail echo Bombardier's enthusiasm for a climatic test facility to test rail passenger cars. They are also interested in dynamic testing and share Bombardier's concerns that static testing does not provide adequate understanding of effects which are associated with windwipe at higher speeds. This effect is primarily of value in performing heat balance tests to assist in heating/cooling system design and insulation and shell design. It is also of value for a wide variety of additional investigations, as defined in Section 2.5 to follow.

2.5 Summary

2.5.1 Summary of Identified Uses

Throughout the various survey and interview processes, ideas were generated concerning possible tests or research that might be undertaken if a large-scale dynamic climatic test facility were available. A great many ideas were presented to the Consultants during the course of the study. Many of these ideas were, in the opinion of the Consultants, not feasible given the current state of the art

in environmental simulation. Many others lend themselves to testing at the component level or do not require a large-scale test facility. There were, however, a number of ideas which do appear to be relevant to the facility under study and these ideas can be classified under three major categories:

1. Clearly defined testing scenarios which were identified by organizations experienced in climatic testing

2. Speculative ideas for tests which would require some form of large-scale climatic test facility, but not necessarily a dynamic one

3. Ideas for research which could be carried out in a large-scale dynamic facility.

These two categories are relevant to the major technical questions which this study attempts to answer. The first category includes the requirements of such organizations as LETE, Bombardier and VIA Rail. These requirements therefore form the basis for the design and evaluation stages of this study. The more abstract research proposals would be accommodated as a side benefit of these requirements.

The second category includes the testing programmes or design problems which would require a large-scale controlled-climate test facility. Most of these ideas were generated by industry and government organizations. For some of the individuals who stated them, these ideas represent little more than speculations. It is very difficult for the Consultants to objectively assess the degree of commitment with which a specific organization would follow up on these ideas and they are therefore presented without any weighting or emphasis.

The screening process applied to test ideas attempted to identify those possible test programmes in which the relevant variables were amenable to control in a fixed facility. For example, several organizations suggested that they might wish to investigate the freeze/thaw action of permafrost around support pilings. It is doubtful whether such a test could be carried out in a general purpose controlled-climate test facility of the type under study. Even if the test were feasible, it is probable that a dedicated test

facility would be more cost-effective. This requirement was therefore ignored when compiling the lists.

A. Definitive Requirements

1. Railway Passenger Car Heat Balance Tests (Dynamic)
2. Railway Locomotive Climatic Testing (Dynamic)
3. Military Vehicle Climatic Testing (Dynamic if possible)

B. Speculative Requirements

i) Railway related testing:

1. Investigations of moisture invasion of traction motors
2. Ore carrier freeze-up
3. Durability and performance of door seals on heated cars
4. Investigations of performance as a function of changing (generally lowering) fuel quality (low temperature starting of diesels)
5. Effects of ice between brake shoe and wheel
6. Restarting warm engines with cold intake air
7. Fuel tank heating performance
8. Air brake performance during cold weather
9. Snow/ice/dust ingestion by propulsion system cooling blowers
10. Operator comfort systems for locomotive cabs
11. High temperature effects on controls, refrigeration equipment and door opening systems
12. Power supply performance for refrigerated cars

ii) Testing in Other Industries:

1. Engine intake location and filtering requirements
2. Cab heating, ventilation, and air conditioning
3. Air brake line freeze-up on passenger buses
4. Heater tests in passenger buses
5. Oil circulation in very cold electrical transformers
6. Performance of switchboxes, insulators and air switches in freezing rain, fog and snow
7. Simulation of solar effects on electrical equipment
8. Oil cooler performance for buses

iii) Research Topics:

1. Research into Enhanced Environmental Simulation

The ability to effectively simulate severe environmental conditions is still subject to a number of restrictions. Snow is perhaps the most notable example of a condition which cannot be comprehensively simulated with current technology. NRC-LTL are one of the world leaders in this field and they are actively engaged in seeking better ways of simulating different types of snow. Mr. Ringer of the LTL suggested that the large scale and controlled airflow of the facility under consideration would allow investigation of new ways of simulating snow accumulation.

Many of the organizations contacted (and particularly the equipment operators) were extremely interested in simulation of dendritic snow crystals. Any significant improvement in this regard would probably result in at least a doubling of projected usage of the facility for industrial testing purposes.

2. Human Factors Engineering

Several organizations expressed interest in exploring the effects of extreme environments on human performance at various tasks. The implications are significant for a wide range of arctic activities, ranging from national defence to resource development. The availability of a large-scale dynamic facility would permit the investigation of wind-chill effects on many tasks.

2.6 Recommended Facility Design Criteria

All of the information gathered during the user survey and the interview process highlights the fundamental difficulty in trying to assess the needs of groups as diverse as those in Canadian industry and government. Because the facility in question has no precedent in North America, very few people in either industry or government have the expertise to be able to assess its potential value to their activities.

There is no ready-made constituency in industry which can provide support and guidance for the development of this type of facility. The staff at the NRC-LTL represent the only knowledgeable organization which is in a position to appreciate both the testing potential and the operating requirements of such a facility. In addition, the NRC-LTL location at Uplands is well suited to the geographical distribution of potential test clients identified by the user survey.

Even more pertinent is the fact that NRC have nearly completed construction of a test facility (the CEF) which will be able to perform all of the static tests (i.e. those which do not require airflow simulation) which the survey identified. The emergence of the NRC Climatic Engineering Facility as a committed project occurred during the execution of the user survey and interviews. At that point it appeared that many of the potential users would be satisfied with a static facility. In order to examined the need for dynamic testing, however, it was necessary to generate a proposed design which was at least plausible in light of the NRC CEF.

The compromise which resulted forms the basis for the design work and evaluation which follows. This compromise calls for the evaluation of a proposed dynamic facility which is constructed as an addition to the NRC CEF. The dynamic facility would be in the form of a closed airflow circuit, with the test section of the CEF made integral to the circuit.

This concept also resolves many of the issues identified during the user survey. Under this arrangement the operation of the facility would be managed by NRC. They would be able to provide the support in test definition, test equipment preparation and similar services that many potential users wanted. NRC have a strong reputation in the field of cold temperature testing and climatic simulation and they have an experienced technical staff which is well regarded in Canadian industry. Finally, several companies expressed a preference for dealing with NRC on the grounds that NRC were regarded as being careful about proprietary information.

Overall, it would seem reasonable that any proposed dynamic facility should take advantage of both the existing investment in the NRC CEF's structure and the accumulated research and testing experience of NRC. A completely new facility might eventually be able to duplicate the NRC resources, but only at a much greater cost.

The concept of a dynamic addition to the NRC CEF thus forms the basis of the engineering study and the cost/benefit analysis in following sections.

3. FACILITY CONCEPTUAL DESIGN

3.1 General

The section which follows will discuss in some detail the technical aspects of a Canadian Dynamic Controlled-Climate Test Facility conceived after the analysis of results from the user survey. It must be emphasized that the design is preliminary and largely conceptual. Implementation will require a preliminary engineering study plus a detail design phase. Performance requirements are based on input from the user survey, plus the Consultants' expertise and experience in the design and implementation of comparable climatic wind tunnels over the last twenty years. Those requirements will be developed throughout this section; then summarized in Section 4.

The facility concepts devised focus totally on the decision of the Steering Committee and the Consultants to pursue an 'add-on' configuration rather than a 'stand-alone' type. More specifically, the dynamic facility will constitute a phased development of the National Research Council's new static Climatic Engineering Facility at the Railway Laboratory complex in Ottawa. The decision was made at the end of the Consultants' presentation of the user survey results to the Steering Committee on November 25, 1981 (Reference 9).

Additional terms of reference for the conceptual design relate to the development of a matrix of cost/benefit ratios (and associated design concepts) for three levels of fundamental facility performance. The original agreement made at the November 25 meeting required the development of facility configurations providing maximum testing speeds (i.e. tunnel airflow speeds measured at the nozzle) of 100, 150 and 200 km/h. Subsequent preliminary investigations by the Consultants demonstrated that the costs for achieving the two higher test speeds would be unreasonably high.

It was agreed by Transportation Development Centre and the Consultants during a meeting on April 14, 1982 (Reference 10) that a maximum test speed of 100 km/h would be provided for all three facility configurations. To facilitate the cost/benefit matrix, each configuration would be provided with different aerodynamic/climatic testing capabilities by virtue of test section design and extent of special test systems. These will be developed in subsections 3.4 and 3.5, and in Table 2.

Artist's perspectives of the general dynamic facility and site layout appear in Figures 10 and 11. For convenience of reference, it will be assumed throughout this section that the long axis of the existing NRC CEF lies along an exact east-west line.

The development of the 'add-on' conceptual designs to follow have been carefully considered relative to available technical information on the NRC CEF. The NRC Division of Mechanical Engineering, and in particular the Railway and Low Temperature Laboratories, have been very co-operative throughout this design phase in providing specifications, drawings and general comments (References 10, 11, 14-16). For the reader's reference, some general drawings of the CEF facility are included with this report as Appendix IV.

3.2 Facility Location

The recommended location for the proposed Dynamic Controlled-Climate Test Facility is at the National Research Council's Railway Laboratory complex near Uplands Airport. Much of the rationale for this recommendation has already been discussed in Section 2. The Uplands site and surroundings are detailed in Figure 12. The complex is located approximately 11 km south of Ottawa's city centre and approximately 1 km east of the Ottawa International Airport's main terminal building. The Laboratory site provides direct access from the CP Rail mainline, plus excellent road access from all directions, without the need to pass through heavily built-up commercial or residential areas.

From a more global point of view, the Ottawa location provides a satisfactory answer to the user distribution patterns projected by the user survey. It is relatively central to all Canadian urban centres, and specifically central to the major industrial concentrations in Toronto and Montreal. It also provides an acceptable compromise with regards to potential U.S. test clients by way of its relative proximity to the heavily industrialized north-eastern states. The extreme distances to Vancouver, Calgary/Edmonton and the Maritimes must be balanced against the low degree of interest in climatic testing amongst potential test clients from those centres. Winnipeg test clients appear to be the only prospects poorly serviced by the Ottawa location, but their numbers are not significant relative to those in southern Ontario and Quebec.

The Railway Laboratory site is also attractive in that it provides local access for test clients to the high-technology research facilities and staff centred at the NRC Uplands and Montreal Road complexes. The location is also consistent with the nearby NRC low and high-speed aerodynamics wind tunnels and the ice ingestion simulator, not to mention the obvious static controlled-climate test facility. In addition, the proximity to a major urban centre guarantees the availability of test support services and suppliers (e.g. machine shops, instrumention suppliers, etc.). At the same time, the relative privacy of the Laboratory site will be attractive to test clients concerned about security during testing of prototypes. The only drawback in this regard is the lack of nearby accommodation for private-client testing staff and personnel.

3.3 Overall Arrangement

3.3.1 General

The overall arrangement of the proposed dynamic facility and new support buildings is illustrated by the artist's perspective in Figure 10, and with more specific detail in the site plan depicted by DSMA Drawing No. E4027-03. Particulars of the wind tunnel layout will be addressed in subsections 3.4 and 3.5. Services and utilities considerations will be treated in sub-sections 3.11 and 3.12. The primary elements of the dynamic facility are:

i) Wind tunnel return circuit

ii) a New 11.0 m long addition to the static facility test section (at its upstream end)

iii) Support Building No. 1 - administrative/operations control

iv) Support Building No. 2 - refrigeration plant and electrical rooms

v) Support Building No. 3 - air make-up/dehumidification system (Facility Configuration 3 only; not shown in Figure 10)

3.3.2 Support Building 1

Support Building 1 will be located at the west end of the CEF alongside the new 11.0 m test section and within the return circuit perimeter. The need for the additional office area and control room provided by this structure arises from discussions with NRC Low Temperature Laboratory representatives (Reference 11).

Reservations were expressed at that time concerning the ability of the CEF to absorb the new staff and control equipment necessary to operate the dynamic facility. In addition, the concentration of dynamic test activities (except for heating balance tests on rail vehicles) in the new 11.0 m test section virtually mandates a new control room alongside that section.

The proposed layout of Support Building 1 is illustrated in DSMA Drawing No. E4027-04. The building will be restricted to a ground floor plus a full basement. Total floor plan area will be 94 m^2, supplemented by a hallway to the main entrances of the CEF's support area. The layout of the ground floor as proposed will be oriented towards contract testing activities for external clients by providing a dedicated office for visiting test staff, a meeting room (which doubles as a staff lounge area), and a reception area. Facility staff are provided with two offices, which will augment existing office space in the CEF's support area. It is recommended that some or all of the latter be turned into a workshop area for the preparation of test equipment and instrumentation.

Support Building 1 will share one wall with the outer shell of the new 11.0 m test section. Three large, heated windows will be provided in this shared wall to permit observation of test section activities from the new Control Room. The new Control Room will house the dynamic facility's control console and computer, along with two or three desks for test engineers. Support Building 1 will be supplied with its own HVAC system, located in the Services Room.

3.3.3 Support Building 2

Support Building 2 contains the dynamic facilty's refrigeration plant, plus the main electrical supply/distribution equipment. The building construction will be relatively simple, with pre-fabricated steel siding applied to a steel structural skeleton. Preferred

location for the building would be within the return circuit perimeter, but this would only be possible with multi-storey construction if the floor area requirement were to be met. That configuration is not recommended for plant equipment purposes.

Support Building 2 will therefore be located alongside the fan leg of the return circuit. This provides immediate proximity of the Plant Room to the main heat exchanger, and also of the Electrical Room to the wind tunnel fan. In a negative sense, however, it will not provide immediate access by testing staff from Support Building 1, and will require moderate-length runs of control and power cabling between the two buildings. The inter-building access limitations may prove troublesome during winter months, and a pedestrian tunnel may have to be considered. Support Building 2 will require a dedicated heating and ventilation system, plus office provisions for at least two stationary engineers. The Plant Room will additionally require an air conditioning system due to the high levels of heat shed by the motors, pumps and compressors housed therein.

Preliminary estimates for floor plan area requirements are 300 m^2 for the Plant Room and 120 m^2 for the Electrical Room with no basement. If chassis dynamometer testing is to be incorporated in the wind tunnel, the Plant Room requirement will increase to 350 m^2 in order to house the larger refrigeration equipment (Electrical Room requirements will remain constant).

3.3.4 Support Building 3

Support Building 3 houses the special-purpose air make-up/dehumidification system required in support to vehicle dynamometer testing (see Sections 3.10.4 and 3.10.5), and is only provided for Facility Configuration 3. The building will be located at the east end of the static facility support area, and will share one wall with the wind tunnel shell. General services (excepting electrical power supply to the associated pumps, heaters and compressor) will be shared with the CEF. Projected floor plan area is 40 m^2, based on single-storey construction with no basement. Construction will be very simple.

3.4 Climatic/Aerodynamic Test Configurations

3.4.1 General

The initial air circuit design required assessing the feasibility of upgrading the NRC CEF to a dynamic capability. The desired maximum test speed was set at 200 km/h, an accordance with the requirements set by VIA Rail and Bombardier representatives during post-survey discussion. If necessary, this would be reduced to 150 or 100 km/h, in accordance with cost acceptability. The dynamic facility would also be adaptable to tests of military and other large road and off-road vehicles. Test section temperatures would be controllable from -30°C to +50°C.

3.4.2 Test Section Design Considerations

The quality of the aerodynamic simulation that can be obtained is directly related to the size of the test section used relative to a given test vehicle. Generally speaking, the test section wall constraints on the airflow makes it difficult to predict the local flow speeds over the vehicle. For this reason, in the past, vehicles with frontal areas only a few percent of the overall test section area have been tested in solid-wall facilities. Blockage (i.e. test article blockage) is the frontal area of a test vehicle divided by the test section flow area. Blockages of 5% to 150% have been tested in semi-open jet facilities, although for the higher blockage cases only flow over small parts of the vehicle was simulated. Rail vehicles, with their large aspect ratios (length to height), are extremely unsuited to testing in high-blockage, semi-open jet facilities if speeds over the front portion as well as the sides of the vehicle must be simulated. Most recently, automobiles have been tested in slotted-wall test sections in order to alleviate some of the wall effects, but for blockages of less than 20%.

The maximum vehicle size assumed in the design process was 3.05 m wide, 4.57 m high and 30.5 m long (References 12 and 13). The available cross-sectional area in the static test facility is approximately 6.1 m x 6.1 m. Testing in a closed-wall facility (Figure 13a) with this degree of blockage (37.5%) is inconceivable under normal circumstances. If, however, the flow over the frontal regions of the vehicle is not of interest (e.g. for passenger rail cars), then windwipe speeds in excess of the nozzle speed can be achieved. The

actual gain in wind speed is a function of the two cross-sectional areas, and increases as the blockage increases. This type of facility is used at the Vienna Arsenal Vehicle Testing Station. If testing of the frontal regions of the vehicle is an important requirement (e.g. for testing locomotives) then the nozzle velocity and the windwipe velocity must be kept approximately equal. In an open-jet facility (Figure 13b), this cannot be ensured for a range of test vehicles and blockages.

The slotted-wall facility shown in Figure 13c is recommended as the best configuration for forebody and windwipe studies of a wide variety of test vehicle frontal areas and aspect ratios. One drawback of the slotted-wall facility is that the artificially high windwipe speeds cannot be obtained unless the slots are somehow blanked off. The slotted-wall configuration normally provides a full-length plenum along the walls and ceiling of the test section. The plenum volume permits alleviation of the extreme pressure rise created as the airflow encounters the leading surfaces of the test vehicle. For the case at hand, it will be sufficient to restrict the slotted-wall segment of the overall test section length to the upstream quarter. This decision is premised on the fact that for extremely long test articles (i.e. rail vehicles), the pressure rise associated with the frontal region of the vehicle can be successfully damped out within the first quarter of the overall vehicle length. For shorter test vehicles (e.g. military equipment, off-highway vehicles, etc.), the partial slotted-wall configuration will be effectively full-length.

3.4.3 Nozzle Speed Evaluation

Nozzle speed evaluations are necessarily a function of nozzle cross-sectional dimensions. The normal design process sees nozzle size tuned to accommodate (amongst other things) nozzle speed requirements. For the case at hand, however, the decision to integrate the NRC CEF's test section into the dynamic facility airline forces the sizing of the nozzle on the basis of conformance with prescribed test section dimensions. With due consideration to this constraint, plus acceptable plenum width, the preliminary recommendations for nozzle dimensions are 4.57 m wide and 5.33 m high, for a nozzle cross-section area of 24.4 m^2. For the maximum vehicle dimensions referenced in the previous subsection, the resultant blockage is slightly less than 60%.

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The calculation of the fan power requirement for a preliminary airline, taking into account the space limitations imposed by site constraints on both the length and width of the overall circuit, quickly revealed significant power penalties associated with the 200 km/h and 150 km/h nozzle speeds. These penalties are illustrated in Figure 14 where the impact of the size and pressure loss factor of the main heat exchanger on the overall fan power requirement is plotted.

It is obvious that a 200 km/h nozzle speed is out of the question and a 150 km/h nozzle speed is only attainable with an extremely large heat exchanger. Aside from the obvious cost penalty of a heat exchanger measuring 12.2 m square, the sheer bulk of such a unit could not be accommodated within the Railway Laboratory site constraints. In addition, the airline cross-sectional dimensions dictated by that size of heat exchanger would have an enormous impact on shell construction costs. The nozzle speed of approximately 100 km/h gives a more suitable design speed. Note that by using the solid-wall test section, windwipe speeds in excess of 200 km/h can still be simulated.

3.4.4 Tunnel Layout Evaluation

The requirement for refrigeration to obtain low test temperatures dictates an airline of the closed-loop or return type. For an open return tunnel, the refrigeration capacity required to bring ambient air to a very low temperature would be staggering. The recommended closed-circuit facility will require sufficient refrigeration capacity to remove fan heat and other test section heat loads while operating at lowest design temperatures. Recirculation of the refrigerated air mass is considerably more economical than continuously treating a fresh charge (as with open circuit designs).

The airflow direction for the circuit is dictated by the access requirements for the test vehicles. It is obvious that access is not available through the settling chamber or contraction; therefore, the contraction must lie to the west of the NRC CEF. In this fashion, the test vehicle will enter the air circuit test section leg by way of Corner 1 (to the east of the CEF).

Additional choices for return circuit layout were also necessary. The first of these choices involved the use of a vertical or horizontal return (i.e. the fan leg runs over top or alongside the test section leg respectively). In view of the relatively restricted site plan around the CEF, a vertical return loop was initially proposed (see DSMA Drawing No. E 4027-02) with the hope of minimizing impact on current and planned NRC activities. Discussions with Mr. R. Ringer (Low Temperature Laboratory) and Mr. C. A. M. Smith (Railway Laboratory) of NRC in February 1982 (Reference 11), led to the ruling out of this configuration on the basis of unacceptable total building height (about 16.5 m above grade).

Horizontal return loop options consisted of placing the fan leg to the north or to the south of the CEF. The latter option was preferred strictly from the standpoint of air circuit design, since it would result in shorter crosslegs (with consequent savings in shell construction costs, plus reduced aerodynamic loss factors). It would also leave the primary access doors to the CEF (along its north wall) unblocked. This preferred option was ruled out at the aforementioned meeting, due to NRC plans for the construction of a railway vehicle fatigue test building in the area that the fan leg would occupy.

Hence, the final return circuit configuration places the fan leg to the north of the test section leg, and necessarily places the existing support area of the CEF within the return loop. It has been agreed by NRC that this layout will be acceptable, assuming adequate provision of personnel underpasses. Removal and replacement of major equipment from the CEF (e.g. compressors) will require the use of a mobile crane.

3.5 Airline

3.5.1 General

The proposed basic airline design appears in DSMA Drawing No. E 4027-01. Total plan dimensions of the circuit are 71.4 m length and 26.7 m width. Nozzle dimensions are 5.33 m height and 4.57 m width (24.4 m^2 area). Main heat exchanger area is 72.3 m^2 and a 5 m-diameter fan is employed. A contraction ratio of 2.4:1 is provided upstream of the nozzle exit plane. A brief discussion of the airline elements follows:

Unsteadiness and flow non-uniformities generated by the test vehicle and the test section structures are damped in the constant-area section between the test section exit and the fan transition inlet. The flow is assisted around each 90° bend by a cascade of turning vanes. The turn vanes assembly at Corner 1 pivots on its inside vertical axis to permit test vehicle entry to the tunnel (see DSMA Drawing No. E 4027-06).

The fan inlet and nose cone provide a smooth transition from a square to a circular flow passage. An overall contraction of the area into the fan provides an increase in the axial flow velocity relative to the fan blade speed and an increase in the relative total pressure uniformity. Both factors directly affect the fan blade loading and efficiency. Long-chord stator vanes remove residual outlet swirl imparted to the flow by the rotor blades. An outlet transition and tailcone provide a controlled expansion of the flow from a circular to a rectangular cross-section flow passage.

Expansion of the flow area in the fan diffuser further reduces the axial flow velocity and hence reduces the flow losses associated with the heat exchanger, turning vanes and settling chamber flow-conditioning equipment located en route between the fan and nozzle.

In the settling chamber the flow encounters a wire-gauge screen, which reduces the turbulence intensity and total-pressure non-uniformities.

A custom contraction design will be employed to minimize the overall length of the contraction. A contour will be chosen which sustains a large adverse pressure gradient without causing boundary layer separation and associated undesirable affects. The contraction will further reduce the turbulence intensity and increase the dynamic pressure uniformity.

The overall airline design reflects an optimization process in which geometric design parameters (circuit length, nozzle geometry, contraction ratio, test section aspect ratio and length, fan diameter, etc.) are balanced against aerodynamic losses, fan power requirements, shell structural costs, flow quality requirements and refrigeration plant size.

The net result is a relatively efficient air circuit providing nozzle flow with uniformity and turbulence intensity performance commensurate with the envisioned climatic testing requirements. Given the available technical data for the comparable Vienna Arsenal Vehicle Testing Station (References 1-7), the predicted flow quality for the proposed airline is projected as at least a three-fold improvement over the European facility.

3.5.2 Test Section Designs

As introduced in Section 3.1 and discussed briefly in Section 3.4.2, the essence of the design and costing matrix for this study centres on the development of three progressively more versatile test section designs. Some of these capabilities are inherently the product of the test section aerodynamic design, while the remainder (e.g. chassis dynamometer) are allocated on the basis of progressively escalated testing capability. The test section configuration options are as follows:

Configuration 1 - full-length solid wall
Configuration 2 - partial-length slotted wall, with convertibility to full-length solid wall
Configuration 3 - as per configuration 2, but with chassis dynamometer and associated ancillary systems added

A full definition of testing capabilities associated with each configuration appears in Table 2. A full discussion of the special test systems for each configuration appears in Section 3.10. Reference should be made to DSMA Drawings No. E 4027-06 and E 4027-07 during the ensuing discussions for each test section design. In general, the test section configuration has no primary influence on the design of the remainder of the airflow return circuit. In each case, the test section is comprised of the existing static test facility length, plus a new 11.0 m upstream addition. The development from Configuration 1 to 2 and 3 is progressive in concept, although probably not amenable to phased acquisition (i.e. retrofit).

a) Configuration 1 (solid wall)

Basic dimensions of the solid-wall test section are identical to those of the nozzle exit plane (i.e. 5.33 m height and 4.57 m

width). For the new 11.0 m segment, this will be accomplished in straightforward fashion by sizing the shell to suit (see Section 3.6). In the NRC static facility segment, it will be necessary to 'sleeve' the test section using a removable liner to create the correct cross-section.

The removable liner will consist of three matched sections. Each section will be a steel plate weldment, with an external steel structural frame. Removal/installation procedure will require the use of a railway flatcar fitted with special-purpose hydraulic jacking frames (not illustrated). When not in use, the liner sections will be stored off the principal laboratory site on dedicated storage pads. A new rail spur line (paralleling the existing trackage to the static facility) will be required for this purpose. Exact location of this spur and storage pad would have to be negotiated with NRC. The liner section structures will be suitably finished with a weather-resistant paint to permit long-duration outdoor storage.

In the solid-walled test section, high test article blockages of up to 60% dictate that the windwipe speed will be significantly higher than the nozzle velocity. An adverse affect of the resultant acceleration and deceleration of the flow over the front and rear portions of the vehicle is the prevention of proper flow simulation in these regions. The capability for achieving high windwipe speeds, however, makes the solid-walled test section well suited to the investigation of heat transfer and airflow over long bodies of relatively uniform cross-sections. Examples of suitable test articles are rail passenger cars and refrigeration cars. Fore and afterbodies should be used ahead of and behind the test article to reduce flow acceleration and deceleration to more acceptable levels at the vehicle front and rear.

The walls of the liner assembly will have a modest divergence (diffusion) angle to account for boundary layer growth along the length of the test section walls and the test article surfaces. There will, of course, be no airflow along the annular region between the liner and the static facility inside walls.

b) Configuration 2 (partial-length slotted wall)

For experiments where proper flow simulation over the forebody of the test article is required, the solid walls would be replaced by longitudinally slotted walls over the length of the new 11.0 m addition. The slots allow some test section air flow diverted by the test article's leading-edge pressure field to be absorbed by the plenum box around the test section. Re-entry flaps located in the plenum box at the end of the 11.0 m test section control the return of this diverted flow from the plenum back into the test section for short test articles (i.e. less than about 9 m). These flaps permit fine-tuning of plenum airflow percentage such that windwipe velocity along the length of the test article can be set approximately equal to the nozzle velocity. For longer test articles (i.e. rail vehicles), the upstream re-entry flaps are augmented by a second set of flaps at the downstream end of the solid-wall liner. In all cases the front end of the test article will be position in the upstream end of the 11.0 m addition.

It should be noted that during tests of short test articles in the slotted-wall mode, it will not be necessary to have the solid- wall liner in place in the downstream test section (i.e. the CEF test section). Conversely, for pure windwipe tests on rail vehicles (as discussed for Configuration 1) it will be possible to revert to the full-length solid-wall configuration. This will be accomplished by manual closure of the hinged filler pieces provided with the slotted-wall slat assemblies, (see 'End View', DSMA Drawing No. 4027-07).

The slotted-wall assembly will be a permanent structure in the 11.0 m addition. The unit will consist of steel main structural support elements, with slats constructed of light-gauge steel sheet fabrications. The slat filler pieces will be constructed from aluminum sheet fabrications to facilitate manual retraction /closure. The main supports will be covered with light-gauge fairing panels to minimize flow disturbances in the plenum region.

On the side nearest the new Control Room (Support Building 1), special heated viewing panels will be fitted in the slat panels to permit observation of the test vehicle by test personnel.

Heated view panels will also be fitted in the near-side wall of the solid-wall liner to permit test article viewing from the old Control Room. Access doors will be provided in both the slotted-wall assembly and the solid-wall liner to allow test personnel access from the Control Rooms to the test section.

c. Configuration 3

In Configuration 3, the test section design remains the same as for Configuration 2 (except for the addition of a flush-mounted chassis dynamometer in the floor of the 11.0 m addition).

3.6 Shell, Insulation and Foundations

3.6.1 General

The proposed general assembly of the Dynamic Facility wind tunnel shell is shown on DSMA Drawing No. E 4027-05. The majority of the return loop shell (i.e. from the first crossleg through to the contraction, inclusive) will be constructed from steel plate, while the remaining test section leg will be comprised by a combination of concrete block outer structure with a sandwich-type insulating panel (Bally panel) inner shell.

3.6.2 Shell Material Selection

In general terms, a fabricated steel shell construction is preferred over poured concrete for applications where higher pressures and wide tunnel air temperature ranges are involved. The lower thermal mass of steel allows for relatively high temperature ranges and rates of change. However, its higher thermal conductivity results in large heat transfer rates through the shell and therefore dictates the use of external insulation.

The steel construction philosophy results in a simple continuous circuit with all components welded together and no expansion joints necessary (except at the interfaces with the concrete shell segments). The main anchoring point will be at the fan housing, with special low-friction sliding support pads provided at all other foundation points to allow for thermally-induced movements of the shell relative to the foundations.

The steel shell construction will permit simple mounting provisions for the internal elements (screens, heat exchanger, turn vanes) and will also enable modifications to be carried out with relative ease.

Noise transmissability of steel shells may pose problems if ongoing NRC activities at the Railway Laboratory site require prescribed noise level limits. Although proper attention to internal noise sources (i.e. fan design) and the use of external thermal insulation will likely relieve this problem, it may prove necessary during detail design to incorporate acoustic insulation material in some regions of the return circuit.

Costs of a steel shell can be estimated with a reasonable degree of accuracy and can, in some cases, be made competitive with a concrete shell. To achieve economy, the amount of shop fabrication should be maximized, implying the transportation of large, prefabricated components to the site. The extent to which this can be realized will be assessable only during detail design.

The use of concrete/Bally panel construction along the test section leg is recommended primarily on the basis of interface considerations with the CEF structure. It is necessary to accommodate in some manner the thermally-induced relative movements between the steel shell structure and the fixed CEF structure. Furthermore, the floor of the test section leg (from the contraction to Corner 1) must be able to accommodate extremely heavy structural loads applied by the inherently large test items to be studied in the facility. It will also be necessary to provide for railway tracks along the floor of the test section leg up to the halfway point of the 11.0 m addition.

Considering all of the above points, it is felt that the shell structure along the aforementioned length of the test section leg will be constructed as a structural steel skeleton with concrete block walls, conventional roof design, and an insulated concrete floor. The actual air circuit will be defined within this outer structure by an inner shell of Bally panels, supported off main structural steel elements. For the case of Facility Configurations 2 and 3, the width and height of this overall structure will need to be expanded by the amount necessary for the slotted-wall plenum.

Interface details with the steel shell segments can be assessed freely with this approach, rather than having to modify the ends of the existing CEF test section structure. Aside from facilitating the design process, this will also minimize the impact on CEF availability while the construction of the dynamic facility's return loop takes place.

3.6.3 Steel Shell Design

The steel shell segments will be constructed from welded steel plate as a continuous structure. Steel structural stiffeners will be added in appropriate sizes and spacings to insure the required accuracy and stability of the shell surfaces during tunnel operation. All exposed steel surfaces (inside and outside walls) will be treated with a corrosion-resistant primer. The turning vane assemblies at all four corners are also constructed as steel weldments. These, along with the fan housing and the main contraction, represent the most cost-intensive elements of the steel shell.

3.6.4 Shell Insulation and Cladding

The steel shell segments of the wind tunnel will be insulated by an external covering of semi-rigid, coated-surface fibreglass insulation mounted by pin impalement. The impalement pins will be welded in place. The fibreglass surface coating will be commensurate with resistance to dust accumulation but will not constitute a moisture seal.

In order to provide a weather-resistant shield for the steel shell's insulation blanket, the shell sections involved will be entirely enclosed by light-gauge, corrugated steel panel cladding. These panels will be mounted on light-duty structural steel standoffs welded to the shell proper. The panels will be pre-painted for durability and attractive appearance. They are not shown on the general assembly drawing.

In the new concrete shell segments along the test section leg, insulation requirements will be met through the use of Bally-type refrigeration panels (steel-insulation-steel sandwich), with appropriate edge flashing, seam sealant and mount standoffs. The exposed steel surfaces will be pre-painted. The two personnel access doors provided in the new test section will be special-purpose, Bally-type

insulated units. The sliding vehicle access door at Corner No. 1 will also be a special purpose insulated unit with appropriate sealing measures. Special measures will be taken at the steel/concrete shell interfaces to assure that mechanical compliance, air circuit integrity and insulation continuity requirements are met.

3.6.5 Insulated Floor

As mentioned earlier in this sub-section, the floor of the test section leg will be an insulated concrete design commensurate with temperature extremes and vehicle loadings. This construction will be used for the entirety of the new test section, as well as from the downstream end of the static facility test section to the beginning of the first crossleg. Implementation will require excavation to beneath the frost line (approximately 2 m below grade). From bottom to top, the floor will consist of a layer of compacted granular fill, followed by a concrete base pad, a high-density styrofoam insulation layer, and topped by a concrete floor pad.

The concrete pads will be poured in place and steel-reinforced. The top slab will use cast-in-place drains at regular intervals to carry tunnel water accumulations (or floor spills) out of the facility. The lower concrete slab will feature a network of cast-in-place, small-diameter vertical drain holes to carry away accumulated condensation from the insulation layer to the granular base layer. The granular base layer will be interspersed by a network of porous drain pipe which will serve to take away moisture and also to heat the bottom of the floor. The latter function will be accomplished by circulating heated air (from the refrigeration machinery area of the static facility) through the piping network. An alternative scheme using an electrical heating grid should be considered during detail design.

The styrofoam insulation layer will extend over the full plan area of the floor and also up the sides and ends of the top slab to its upper surface level. The top slab will be poured with a centre trench for the rail track, such that the tops of the rails will be level with the test section concrete floor. Conventional gravel ballast and wooden sleepers will be used in this trench to create the track bed.

The vehicle access rails will have to be provided with breakpoints at the three vehicle access door locations (i.e. the upstream and downstream ends of the static facility test section, and at the Corner No. 1 main access door) in order to permit door closure. This will be accomplished by the provision of removable, 400 mm-long rail segments in both rails at all three of these locations. These segments will be provided with welded base plates to permit them to be bolted to raised concrete mounting pads (cast-in-place as part of the floor slab) when required.

Resilent insulating/expansion strips will be required between the abutting ends of the new top floor slabs and the existing top floor slab in the static facility.

Provision of an inspection pit as part of the new floor would be feasible, but limited in length (i.e. it would have to fit within the length of the 11.0 m test section addition). The dynamometer pit might serve this purpose in Facility Configuration 3, if the dynamometer machinery is temporarily removed.

3.6.6 Foundations

All foundation pads for the steel shell are steel-reinforced concrete blocks with embedded steel locating elements. The locations of these foundations will be as shown in DSMA Drawing No. E 4027-05. With the exception of the fan housing and Corner No. 4 locations, all of these foundations will employ the sliding-pad principle for shell support. The fan housing foundation will feature bolted-in-place location for that shell element. At Corner No. 4, the central foundation will use an articulating locator for the shell in order to constrain thermally-induced motion to a known path.

3.7 Fan and Drive

The fan and drive system is comprised by the rotor, blades, nacelle, stator blades, plus motor and drive (with associated lubrication and cooling systems). The proposed scheme includes a high-performance, single-stage axial fan with adjustable-pitch (wind-off) blades. Exact and final specifications can only be determined during the detail design phase, but preliminary investigations call for a blade tip diameter of 5.0 m and a hub-to-tip diameter ratio of 0.5. Estimated inertia of the fan/rotor assembly is 270 kg-m^2. It must be

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noted that the proposed variable test section creates a difficult fan design problem, since large differences in pressure rise occur from one test section/test article combination to another. A preliminary review of available proprietary designs indicates that the fan will have to be a custom design in order to guarantee maximum performance and efficiency with acceptable noise levels. Variable- pitch inlet guide vanes may also be necessary in order to meet performance requirements. A conservative value for fan efficiency of 0.75 will be used during subsequent performance and power requirement analyses. The Consultants believe that this figure will likely be increased to 0.80 or better during detail design.

The fan drive will be based on a variable-speed DC motor, nacelle-mounted within the air circuit. The nacelle itself is supported within the fan housing by the stator blades. An additional set of 'stator' blades will be necessary midway along the length of the outlet transition to support the tailcone. SCR (thyristor) speed control in conjunction with DC drive is recommended as the most suitable solution for the performance and operating economy requirements of this application. Motor and fan rotor will be direct-coupled. The motor will require Class F windings insulation to support operation at elevated temperatures.

In order to restrain already-high drive power requirements, the drive system will be designed for essentially steady-state operation. This will limit dynamic testing to essentially constant air velocity conditions (i.e. gust simulation and fast transient response measurements will not be possible). The maximum fan design speed will be 540 rpm, with a turndown ratio capability of 10:1. 'On-line' dynamic (regenerative) breaking will not be provided.

Speed control accuracy to within 1% of maximum design value is recommended as compatible with the anticipated test requirements. Speed control functions along with safety interlocks are the responsibility of the Facility Support System and will be discussed in Section 3.9.

The fan drive system will be supplied with a suitable pressurized lubrication system for the motor bearings. During high-temperature operation, the motor will be cooled by a separate supply of ducted, forced air from an external source.

Maximum shaft power requirements for the fan are dominated by the high-blockage, solid-wall test case for rail vehicles (i.e. heat balance tests for passenger rail vehicles). In this configuration, a power requirement of 2.28 MW has been estimated. For the high-blockage, slotted-wall test configuration, maximum fan shaft power requirements drop to 2.06 MW. For low-blockage, slotted-wall tests (e.g. testing of large military vehicles), power requirements drop to 1.97 MW.

It should be noted that the 2.28 MW shaft power requirement applies as a maximum to all three facility configurations, despite the use of the slotted-wall upstream test section in Configurations 2 and 3. This is based on the capability for converting that slotted-wall section to a solid-wall configuration (as discussed in Section 3.1), such that heat balance tests are possible for rail cars in all three facility configurations.

3.8 Cooling/Heating System

3.8.1 General Design Requirements

The function of the wind tunnel cooling/heating system is to maintain a given temperature in the wind tunnel airflow by the removal or addition of thermal energy. Heat is produced in the tunnel by the main fan, and in the case of thermodynamic (dynamometer) testing, by the test vehicle and by the solar simulation system (if in use). Heat is also released in the latter case by the make-up air dehumidifier and brine pumps. Additionally, heat from the outdoor environment is transmitted to or from the airstream through the wind tunnel insulated shell. Control of the tunnel air temperature will be carried out by a main air-to-liquid heat exchanger.

The required capacity of the cooling/heating system is a function of the minimum working temperature, the temperature range and the cooling load on the system. It is also influenced by the required time rate of temperature change. For a given cooling system, temperature pulldown (with respect to time) in the wind tunnel may be approximated as an exponential function. Thus, the initially rapid temperature reduction progressively slows as lower temperatures are attained. This implies that realistic limits for cooling rates over the total temperature range are necessary in order to avoid oversizing

the related equipment. Excessive rates of temperature change will have a direct impact on the facility cost due to hardware, and also on the Plant Room size required to house that equipment.

The general arrangement of the cooling system is dictated by four main considerations. The first of these is the necessity for small air-to-brine temperature differences, measured widthwise across the main heat exchanger, to ensure good temperature uniformity. The second is the wide range of temperatures and loads over which the system is expected to operate.

The third is the requirement for acceptable temperature pulldown times, and the fourth, ease of operation and maintenance. Simple plant operation by the tunnel operators is desirable. Once started, operations will be fully automatic except for manual emergency overrides. Adequate modulating and safety controls will be provided to ensure such operation with a minimum of supervision. These will be discussed separately in Section 3.9.

3.8.2 Proposed System Elements

a. Compressors

The cooling load profile for the proposed dynamic facility is approximately constant, essentially independent of temperature, and suitable for screw-type refrigerations systems operating at constant speed. Reciprocating compressors are not recommended because their limited capacity would necessitate a large number of units, with commensurate expense and complexity in controls and piping. Centrifugal compressors do not lend themselves as well to the wide range of operating temperatures required, while absorption units are unnecessarily expensive for the application at hand. On this basis, screw-type compressors are recommended for the cooling system. This type of compressor has been used successfully on seven of DSMA's climatic test facility designs.

The range of temperatures over which cooling is required is very wide and, at the lowest temperature conditions, exceeds the capability of single-stage compression. One or more booster compressors for the low-stage duty will be required. Multiple high-stage compressors will also be required. Predicted requirements will be detailed in Section 3.8.4 for each of the three facility configurations.

b) Main Heat Exchanger

The controlling factor in selection of the air-to-liquid main heat exchanger is the air-side velocity. The air-side film heat transfer coefficient varies approximately as air velocity to the 0.6 power, whereas the heat produced by the fan varies as air velocity to the power of 3. The air-side heat transfer coefficient is poor under the best of conditions when compared to the equivalent coefficients on the brine side. This must be offset by increasing the air-side surface area through proper design of fin geometry, with a surface area ratio on the order of 10:1 to 15:1.

In addition, temperature uniformity over the width of the heat exchanger must be promoted by keeping the air/brine temperature difference at around 10°C. This results in a requirement for multiple-row heat exchangers of plate-fin or discrete-fin arrangements (and hence higher losses). Spiral finning is not recommended since it results in vortices with subsequent flow quality degradation.

The selection of the heat exchanger is necessarily part of the integrated tunnel design since pressure loss, fan power, flow quality, and refrigeration equipment are all directly affected by its choice.

c) Brine/Refrigerant

The selection of the brine and refrigerant is based on fluid dynamics, heat transfer, toxicity, and flammability characteristics. At low temperatures, most conventional brines (calcium chloride, ethylene glycol, and propylene glycol solutions) become quite viscous, severely degrading their performance as heat transfer fluids. Trichloroethylene, however, offers good heat transfer and fluid flow properties at low temperatures, with low flammability and relatively low toxicity at ordinary temperatures. For the refrigerant, fluorinated hydrocarbon types comply best with the toxicity and flammability requirements. Based on previous facility design and operational experience, the recommended brine and refrigerant for the dynamic facility cooling system are trichloroethylene and a fluorinated hydrocarbon respectively (selected to best suit the load/temperature conditions required).

3.8.3 Cooling System Operation

DSMA Drawing No. E 4027-08 shows a schematic flow diagram for the main components of the proposed dynamic facility cooling system. The system consists of a cooling water circuit, a refrigerant circuit and a brine circuit, working in conjunction with the air circuit (and the make-up air system for Facility Configuration 3). For simplicity, the high and low-stage compressors are each shown as single elements.

The main heat exchanger (HX 104) is located in the fan diffuser of the wind tunnel, with a face area equal to the full cross-section of the diffuser. Air passing over the heat exchanger gives up heat to the cooler brine circulating within the tubes. Pump P102 ensures a continuous, constant flow rate. The temperature of the brine is controlled by mixing a quantity of cold brine from the supply line with the warmed brine leaving the heat exchanger. In this manner, the exact brine temperature can be obtained to cool the tunnel air to the desired temperature. Warm brine not recirculated is piped to the return line. Thus, the brine circulating through the heat exchanger results in a constant-flow, variable-temperature system.

The brine flow leaving the main heat exchanger collects in the return line and is piped to the brine chiller (HX 103), a shell-and-tube heat exchanger. Here the brine is cooled to the desire temperature by a transfer of heat to the cooler refrigerant. The brine flows through the tubes of HX 103, while the refrigerant evaporates on the shell side.

The brine expansion tank (T102) connected to the brine supply line serves the usual function of providing space to accommodate the considerable change in volume of the brine charge. The tank is closed and is provided with a dry-air pressurizing and relieving system.

The heat absorbed by the refrigerant in chiller HX 103 causes some of it to evaporate, thus maintaining the body of liquid at a relatively constant temperature. The refrigerant vapour is drawn out of the chiller into a suction line leading to the low-stage, screw-type compressors (C102). The discharge from these compressors is then piped to the inlet of the high-stage, screw-type compressors (C101).

The condenser (HX 101) is a shell-and-tube heat exchanger with refrigerant on the shell side, and water from an evaporative condenser cooling system passing through the tubes. Heat transferred from the refrigerant to the cooling water first de-superheats the refrigerant and then causes it to condense.

The warm, saturated (or slightly sub-cooled) liquid refrigerant drains from the condenser into a receiver (T101). The receiver is vented back to the condenser to prevent vapour binding. The receiver functions as a storage tank to hold the extra refrigerant charge in the system; as the temperatures and loads change, the level in the receiver will vary. A further benefit provided by the receiver is its ability to store the cooling system's complete refrigerant charge should servicing be required on any component.

Liquid refrigerant from the receiver is piped to an intercooler/economizer (HX 102) where its temperature is partially reduced. The intercooler/economizer may be arranged as an open or closed unit. The resulting flash gas is piped to an intermediate opening in the high-stage compressors (C101) to undergo partial compression. The net result of this scheme is to reduce the compressors' drive power under high load conditions, and to increase the system's low-temperature capacity during staged operation.

From the intercooler, liquid refrigerant is piped back to the brine chiller (HX 103). Here, a level-controlled feed valve functions to limit the flow to just match that which is being evaporated in the chiller, thus maintaing a constant liquid level. As the refrigerant liquid passes through the control valve, a large drop in pressure occurs. This causes a portion of the liquid refrigerant to flash, with a consequent drop in the temperature of the remaining liquid.

To supplement the inherent tunnel heating capability provided by the various heat energy sources (e.g. fan), the brine circuit is provided with an electrical heater. Obviously, heating the tunnel air mass is a much easier proposition than cooling it.

3.8.4 System Performance and Sizing

As discussed in Section 3.1, the cooling/heating system performance will be assessed for all three Facility Configurations in accordance with the basic requirements for a minimum test temperature of -30°C

and a maximum temperature of +50°C. Preliminary assessments of hardware and power requirements for transient temperature tests (i.e. rapid temperature changes) indicated unreasonable increases in an already large cooling system capacity. For this reason, the system will be sized for the loads imposed by essentially constant-temperature, constant-air speed requirements.

It was hoped in the early conceptual stages that the capacity of the existing static facility cooling system could be used to achieve a worthwhile augmentation to the dynamic facility's system. Subsequent investigations, however, showed that the static facility's system (sized at about 200 kW) would be at least an order of magnitude less than the requirements for dynamic testing. Attempts to integrate this system with the new dynamic facility system would result in unreasonable interconnection costs and complexity relative to the small supplement achievable. Nevertheless, the CEF system can be put to use in a fashion which will be discussed shortly.

Evaluation of the thermal loads for each of the Facility Configurations has produced the following preliminary estimates for cooling system capacity:

Configuration 1: 2.64 MW
Configuration 2: 2.64 MW
Configuration 3: 3.14 MW

The above figures reflect worst-case scenarios for Facility Configurations 1 and 2 (i.e. summer ambient conditions, maximum test article blockage, maximum test speed, minimum air temperature, solid-wall test section mode). For slotted-wall testing of lower-blockage test vehicles (blockage of about 40%) under the same maximum-speed/minimum-temperature conditions, the system capacity would drop by approximately 200 kW for Configuration 2. The capacity quoted for Facility Configuration 3 represents a slightly different worst-case scenario. Maximum speed/minimum air temperature/summer conditions are again assumed, but in this case a slotted-wall configuration with mid-range test article blockage (38%) and full vehicle heat rejection (730 kW) are used in the analysis. All capacities quoted here are rated capacities, and do not constitute electrical power requirements. The latter will be treated in Section 3.11. Preliminary projections call for two compressors each in the high and low stages (total of 4) for

facility Configurations 1 and 2, and three compressors each (total of 6) for Facility Configuration 3.

In all cases, the estimated system capacities constitute extremely large plants and will contribute several million dollars to the acquisition cost of the facility. Hence, temperature pulldown performance deficiencies must be evaluated with caution. Assuming that only the basic plant capacity is installed, preliminary estimates suggest that under worst-case ambient conditions (i.e. outside temperature +32°C, high humidity), it will require a minimum of six hours to pull tunnel air temperature down to -30°C. Assuming an 8-hour shift for the plant supervisory staff, this would leave little or no testing time at the end of the day.

Although the plant will be designed for automatic control, it would be inadvisable (and contrary to existing provincial codes) to sustain unmanned operation overnight in anticipation of next-day testing. That scenario would also have significant impact on overall facility operating costs by requiring two additional shifts for the plant supervisory staff compliment. With this in mind, it it is recommended that the smaller refrigeration plant of the static facility be used after the initial large-plant pulldown period to sustain tunnel air temperature at an intermediate overnight value. The large plant would be re-activated at the beginning of the second day for a final 2 to 3-hr. pulldown to -30°C. The dynamic facility main fan would remain in operation at low speed during the overnight hold in order to maintain low-level air circulation. Preliminary estimates suggest that the static facility plant would be capable of maintaining a tunnel air temperature of -5°C under worst-case ambient conditions.

It must be emphasized that the pulldown performance estimated in the preceding paragraphs is specific to low-temperature testing during extreme conditions. The same applies to overall plant capacity estimates. Nevertheless, it is felt that this is the only reasonable planning strategy for the dynamic facility if its full usage potential is to be realized.

3.8.5 Options for Reduced Operating Temperatures

The system proposed thus far (including capacities, pulldown performance, hardware extent, and acquisition cost) will be suitable for worst-case operations to -30°C. As part of the terms of reference for this study, it was agreed that additional low-temperature options of -40°C and -50°C would be investigated with regards to budget cost estimates. The implications of these two options are as follows:

ITEM	-40°C	-50°C
No. of compressors	8	14
Capacity Increase Factor	1.5	2.5
Plant Room Size Increase Factor	1.3	2.0
Pulldown Time (minimum)	8 hr	12 hr
Acquisition Cost Increase (minimum)	$2 M	$6 M

The above considerations only begin to illustrate the impact of these lower temperature options. Pulldown performance will become critical, and probably necessitate 3 shifts-per-day plant supervisory staffing. Some materials selections implementable in the -30°C configuration become marginal or unacceptable for lower operating temperatures, forcing more costly alternatives. Shell insulation costs will increase significantly. Fan power increases will be required to overcome the additional flow losses introduced by the requisite main heat exchanger size increases. Necessary electric utility requirements increases may be deemed intolerable by the local utility and will certainly force significant increases in both the power distribution system's cost and in facility electric power usage costs.

3.8.6 Vienna Arsenal Vehicle Testing Station Evaluation

At the outset of the conceptual design process, an extensive review of available literature was carried out regarding the Vienna Arsenal Vehicle Testing Station and its performance capabilities (References 1-7). Reference 4 provides the most comprehensive documentation, with specific attention given to the results of the commissioning programme carried out after the extensive upgrading of the facility in 1974.

The initial specifications for the upgrade called for 300 km/h windwipe speeds for a temperature range from -50°C to +40°C. These requirements were abandoned after a preliminary analysis suggested unacceptably high costs. The final design specification fell back to a more modest requirement for 200 km/h at a temperature of -20°C, and 250 km/h at 0°C.

It must be pointed out that the Vienna Arsenal documentation uses a somewhat questionable method for assigning maximum windwipe speeds. The quoted velocities in the literature refer to the peak air speed achieved over the width of the annular gap between the test vehicle and the test section wall (their reference vehicle is a UIC Type X vehicle, which creates a blockage of 63% for the 24 m^2 test section). Naturally, this peak value occurs at about the midpoint of the gap, and air speed falls off exponentially to zero at the test section wall and the test vehicle surface. The mean air speed value calculated (by one-dimensional analysis) for the entire annular gap width would be 14% less than the peak value, and is felt to be a more realistic method for portraying windwipe speed. Windwipe speeds for Facility Configuration 1 are given in Section 4.1 as mean speeds, with a value of 225 km/h at -30°C projected for the 60% blockage case (versus 172 km/h at -20°C for Vienna Arsenal).

The Vienna Arsenal dynamic facility is fitted with a 2.0 MW fan drive, and a refrigeration plant rated at 1.1 MW capacity at -20°C. Volumetric flow rate at -20°C reaches a maximum value of 432 m^3/s. The commissioning data from Reference 4 shows that test temperature can be maintained to within 0.5°C at -20°C for the design air speed of 172 km/h. There are strong indications from the same data, however, that the fan drive is overpowered (probably because the total loss factor for the circuit was overestimated). In addition, the commissioning data suggests that deficiencies in either the refrigeration plant design or the shell insulation prevent satisfactory temperature control (at design air speed) for temperatures above +20°C. It must be emphasized that successful climatic wind tunnel performance requires not only the ability to reach design temperature at design air speed, but also to hold temperature drift to reasonable limits for long periods of time (say ±0.5°C for at least 12 - 15 hours).

In some respects, the airline configuration of the Vienna Arsenal dynamic facility is quite similar to the proposed Facility Configuration 1. Both have test section cross-sectional areas of roughly 24 m^2, and both feature a continuous diffusion angle along the test section length. In addition, the location of the main heat exchanger in the fan leg near Corner 3 is common to both airlines. Fan diameters are also fairly close, at 4.5 m and 5.0 m respectively.

The notable improvement in the proposed airline (Facility Configuration 1) over that of the Vienna Arsenal dynamic facility is the incorporation of a nozzle prior to the test section. In addition, Facility Configuration 1 is designed for much higher volumetric flow rates (610 m^3/s at -30°C) with full temperature control to -30°C (hence, a heat exchanger face area 1.8 times that of Vienna Arsenal). Simply put, the proposed design promises much greater performance in terms of both testing speed and temperature.

There are some other aspects of the Vienna Arsenal dynamic facility which deserve comment. First, the refrigeration plant uses a turbo-compressor (centrifugal) machine. The Consultants believe that this choice is most appropriate to applications where only one or two temperature set-points are required. Screw-type machines are recommended for the proposed facility to best accommodate the wind range of anticipated operating temperatures.

Second, the Vienna Arsenal dynamic facility's test section is a fixed configuration suitable only to windwipe studies for long, continuous-cross-section vehicles at high blockage ratios. Climatic tests of short, medium-blockage vehicles (e.g. military equipment) would suffer from extremely poor airflow simulation. The slotted-wall designs of Facility Configurations 2 and 3 have been proposed to overcome this limitation.

On the positive side, the Vienna Arsenal dynamic facility features a pit- mounted dynamometer (absorbing only) for investigations rail vehicle brake system performance. It must be noted that this special test system does not permit investigations of locomotive powerplant performance (the proposed facility's refrigeration system is entirely inadequate for this purpose, not to mention the absence

of the necessary exhaust extraction and combustion air make-up systems). Nor is it suitable for non-rail vehicles. For automobiles, a removable chassis dynamometer (absorbing only; rests on the floor rather than in a pit) has been used. The Vienna Arsenal dynamic facility's test section also features a solar simulation system, consisting of approximately 1000 'infrared' lamps arranged in a bank of about 22 m length and 3.5 m height (77 m^2 total area). Total power of the lamp bank is given as 200 kW (Reference 23), but the spectral distribution qualities of the lamps are unknown.

3.9 Control and Data Acquisition (Facility Support System)

3.9.1 General

The 'add-on' nature of the proposed dynamic CCTF requires a considerable degree of flexibility in the Facility Support System in order to provide adaptability, versatility, reliability and maintainability. The Facility Support System has two main functions:

1. Dynamic Facility Control
2. Data Acquisition

An overall schematic of the control and data acquisition functions is shown in Figure 15. Computer-based systems will be the logical choice for implementing a Facility Support System with these requirements.

Experiments in the dynamic facility will be conducted at basically steady-state conditions with respect to air temperature, speed, humidity, and other controlled parameters. Transient data will generally not be required, except for monitoring purposes. As a result, there will be no need for precise synchronization between the control and data acquisition functions, and it will not be necessary to provide a sophisticated interface between them. Neither will there be a need to have the two functions residing in the same physical computer system.

The subsections which follow describe the functional requirements and configurations of the Control and Data Acquisition subsystems. The proposed computer configurations are based on making full use of the computer system already available at the NRC CEF.

Although this may not be the best technical configuration, it is judged to be the most cost-effective implementation of the control and data acquisition functions.

3.9.2 Control Functions

The Dynamic Facility Control System (DFCS) will support the following basic functions:

1. Parameter Control
2. Facility Safety Interlocks
3. Operator Interface

The DFCS will control the parameters which are listed below to operator-entered set-points. Programmable experimental sequence definition will not be supported since the experiments will be mostly slow, steady-state tests. The control system will ramp the parameter set point to the desired target set by the operator, at a predetermined rate. The control algorithm will control each parameter to its current set point. For loops with external auto/manual switching, the control system will provide 'bumpless' transfer from manual to automatic status. Note that several new subsystems (items iii - iv and viii - xi) are introduced in the list to follow. These systems will be described in detail in Section 3.10 to follow.

i) Windspeed: Windspeed will be controlled via the fan speed controller. Due to the variation in tunnel time constants throughout the windspeed range, an adaptive controller will have to be used to provide good performance throughout the entire range. Manual control of the fan speed independent of the computer will be provided.

ii) Air Temperature: Air temperature will be controlled via the heat exchanger mixing fraction. The temperature target will be entered at the operator's console. The air temperature set point will be ramped to the target at a predetermined rate. The controller will use feedforward/feedback control to achieve reasonable response on air temperature. The feedforward control will include information from heat sources (e.g. fan speed, tunnel metal temperatures, and test vehicle surface temperatures). The controller gain will be adaptive to the operating conditions (e.g. wind speed, brine temperature and

main heat exchanger brine outlet temperature) to give stable and reasonable performance under all operating conditions. Manual control of the main heat exchanger mixing fraction through the computer will be provided.

iii) Humidity: Humidity will be controlled through the actuation of a steam valve. Manual control of the steam valve through the computer will be provided. The DFCS will also control actuation of the steam generator.

iv) Dynamometer (Facility Configuration 3): For dynamometer testing of non-rail vehicles, the dynamometer speed or load will be controlled through a dynamometer controller. The speed or load selection will be entered through the operator's console. The set point will be communicated to the dynamometer controller.

v) Make-Up Air Control (with dynamometer option): Make-up air will be controlled to maintain the static pressure of the tunnel. The make-up air flow will be controlled by make-up air fan actuation (on/off) and by damper position; the temperature of the make-up air will be controlled by brine flow rates through the high and low-temperature make-up air heat exchangers. Low-temperature heat exchanger defrost cycles will also be controlled by the DFCS.

vi) Test Engine Exhaust Extraction (with dynamometer option): Exhaust gas extraction will be controlled through the speed of the exhaust fan. The set point will be derived from the pressure sensors in the vehicle exhaust pipe and in the test section ambient.

vii) Re-entry Flap Control (Facility Configurations 2 and 3): The pressure gradient along the test section wall will be controlled by re-entry flaps at the end of the slotted-wall plenum. Position set points for the two sets of flaps will be entered at the operator's console at the beginning of the experiment, and will be held constant throughout the test. Position set points will be determined by the Test Engineer during preliminary tests before the main experiment takes place (by observing pressure gradients in the test section with the test article in place for various flap positions).

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viii) Purge System (with dynamometer option): Tunnel air will be purged by actuating (on/off) the purge fans.

ix) Solar Simulation (Facility Configurations 2 and 3): Intensity (W/m^2) of the solar heating load applied to the test vehicle will be set at the operator's console. Intensity levels will be precalibrated during initial commissioning of the system. Occasional re-calibration will be done using portable equipment and the calibration factor will be entered through the operator's console.

x) Rain Simulation (Facility Configurations 2 and 3): The rain rate will be controlled by modulating a control valve in the supply line to the water spray nozzle. The DFCS will also control actuation of the water supply booster pump.

xi) Freezing Rain Simulation (Facility Configurations 2 and 3): Freezing rain will be produced by controlling the throttle valves in the pressurized air and water lines to the spray rake. The DFCS will also control actuation of the air compressor and the water booster pump.

The control computer will also monitor status of the test facility and issue permissives for the control functions. These will include the following:

1. Fan interlocks: The main fan will be turned on only if the CEF test section's end doors are fully opened and the Corner 1 external door is closed. An actively-controlled pressure relief flap will be fitted in the tunnel shell just upstream of the nozzle to guarantee protection from under/overpressurization. The purge fans will be turned on only if the main fan is shut down (and conversely).

2. Heat Exchanger Interlocks: The main heat exchanger and make-up air heat exchangers will be interlocked with the appropriate fan/damper status and the refrigeration system to ensure active cooling.

3. Emergency Pushbutton: When the emergency pushbutton is activated, all control functions will abort to a safe state, (e.g. fan speed at zero, main heat exchanger at recirculation, steam valve

closed, steam relief valve opened, steam generator shut down, etc.).

The DFCS will interface with the operator through a CRT terminal. For convenience, two CRT terminals will be provided for control: one terminal located in the static facility control room where the Data Acquisition Computer is located; the other located in the new control room. Depending on the type of testing being done, the tunnel will be controlled from one of the two control rooms. Active control will be available on one selected terminal only. The operator interface will be interactive and menu-driven. There will be four types (or levels) of operator interfaces:

i) Tunnel Status - displays measured air temperature, coolant temperature, heat exchanger outlet temperature, dew point, steam grid temperature, dynamic pressure, total pressure, fan speed, etc. Control parameters will be displayed in graphic form, with set-points. Tunnel status can also be logged at regular intervals. Alarms will be generated and logged if parameters exceed their control set-points by more than predetermined margins.

ii) Control Status - displays control modes, process variables, targets, set-point values, controller outputs and update rate for all of the control loops. The operator will be able to change the targets of the control loops. Set-points will be changed with predetermined rates until target is achieved.

iii) Loop Parameters - displays and allows modification of control loop parameters for all control loops. Controlled parameters will typically include normalized gain, reset time, filter break-points and break-point ratios.

iv) System Commands - involves direct communication with the system executive for start/stop control, power-up/power-down, and system backup. This mode is not expected to be frequent and will not be menu-driven. Protection functions (e.g. operator command confirmation) will be used at this level to avoid inadvertent use of system commands.

3.9.3 Data Acquisition Functions

The Data Acquisition System will provide primary support for collection of sensor signals from the test item. The number of signals to be scanned and the scanning rate will be dependent on the experiment to be performed. These scanning parameters will usually be defined only after the experiment has been defined. The data acquisition system will be designed for easy modification in order to accommodate the anticipated high variability in experiment types. For the data acquisition side, the following requirements exist:

i) Pseudo Channel Assignment - Allows the user to assign symbolic names to channels, so that the user does not have to address them by their physical address and characteristics.

ii) Sensor Library - Storage of sensor-specific calibration coefficients for temperature, pressure and flow measurements.

iii) Auto Calibration - The system will include a procedure to calibrate the sensors before an experiment. This calibration will be on the sensor only, or on the entire input channel.

A 'user-friendly' data acquisition software concept will be applied to the report generation and data management functions. Reports will be in tabular or graphic form. The system will allow the use of pseudo-channels for reporting and plotting.

The data acquisition system will provide data archival and retrieval capability. This is needed primarily for data comparison between experiments.

3.9.4 Hardware Configuration

The control system computer configuration is shown in Figure 16. The actual number of Input/Output cards required will depend on the optional control functions. The basic control system will consist of an ADAC 1000 (LSI 11/23)-based microcomputer system. The system will have a power supply, card cage, backplane, and the following cards:

i) 1823HF KDF11-AA LSI 11/23 processor with KEF11-AA floating point instruction chip and 128 kb random accessory memory.

ii) MXV11-AC multifunction card with 32 kb memory and two synchronous serial lines
iii) 1750-0 two port serial I/O
iv) 1800C KWV11 - A real time clock
v) DSD 880D8 Winchester and floppy discs
vi) 1012-EX, 1014 high-resolution A/D converter system
vii) 1112RL-16 Thermocouple input module
viii) 1412DA Digital-to-Analog converters (2 required)
ix) 1616 Optically-isolated digital I/O modules

For mass storage the system will have a Winchester disc (5.2 Mb) with a floppy disc (512 kb). Operator interface will be through two VT100 terminals. An LA-38 hard-copy terminal will be used for logging. The signals used for control will include the following:

i) Dynamic pressures (wind speed)
ii) Static pressure
iii) Motor speed (fan speed)
iv) Tunnel air temperature
v) Tunnel and test item surface temperatures
vi) Brine temperature
vii) Heat exchanger(s) outlet temperature(s)
viii) Dynamometer speed/load (with dynamometer option)
ix) Make-up air temperature (with dynamometer option)
x) Auto/manual status
xi) Support equipment status
xii) Static Facility control equipment status

The output from the control computer will typically consist of the following:

i) Fan speed set-point
ii) Heat Exchanger(s) mixing valves position set-points
iii) Steam valve position set-point
iv) Rain and freezing rain control set-points
v) Static Facility equipment (existing) equipment control interface
vi) Re-entry dampers position set-points (with slotted wall option)
vii) Dynamometer speed/torque set-point (with dynamometer option)
viii) Make-up air damper position set-points (with dynamometer option)

ix) Defrosting heater set-points (with dynamometer option)
x) Purge system damper position set-points (with dynamometer option)
xi) Engine exhaust extraction fan set-point (with dynamometer option)

The computer equipment described represents a typical configuration. The final configuration would be decided at the detail design stage.

3.9.5 Data Acquisition System Configuration

The Data Acquisition and Display Computer will be based on the existing HP-3054 system in the NRC CEF. This system consists of :

i) HP 9845B desk top computer with 187kb memory
ii) HP 3497 Data Acquisition and Control Unit
iii) HP 3456A Digital Voltmeter
iv) One 16-channel Digital Input card
v) One 16-channel Digital Output card
vi) Relay multiplexers

The basic unit can accept a total of five I/O assemblies. After accounting for the digital I/O cards, a maximum of 60 analog channels can be available on three assemblies. This is quite sufficient for the experiments envisaged for the Dynamic Facility. These tests might require, for example:

1. Up to 40 temperature measurements (on, or within the test item)
2. Wind speed
3. Air temperature
4. Humidity

If further expansion is required, it can be done by using an HP 3498A expansion box together with the appropriate I/O module assemblies. If, for example, heating balance testing of passenger rail vehicles required the collection of data from approximately 200 channels (mostly thermocouples), these could be accommodated by the addition of 10 or 12 I/O modules at a hardware cost of about 10,000. This strategy would assume that sampling rates would be relatively slow (e.g. scanning of all 200 channels in about 5 seconds).

3.9.6 Safety Systems

Some of the interlock systems controlled by the DFCS have already been introducted in Section 3.9.2. A more detailed discussion of the overall Safety System follows:

Several systems will be required to ensure safe operation of equipment and a safe working environment for the facility personnel. The fan drive, dynamometer, and refrigeration compressor systems will be supplied with self-contained sensors and interlocks to ensure their safe operation. In addition, a number of facility-wide interlocks will be required for the safe operation of the overall dynamic facility.

The main interlock and safety shutdown logic are implemented in the DFCS. The occurrence of an unsafe condition or the existence of an interlocked condition which prohibits a desired action will be displayed on the operator's console. The appropriate action, such as shutdown of the main fan or reduction of fan speed, will then be taken automatically by the DFCS.

A low-level (i.e. relays) shut-down circuit ("fault buss") will be provided to effect the shutdown of the main fan, etc. upon the occurrence of certain subsystem failures or unsafe events. This includes in particular failure of the DFCS, high combustibles levels, or unauthorized personnel entrance to the facility.

Three separate gas analyzers will be supplied (housed in the basement of Support Building 1) to monitor the respective ambient levels of CO, hydrocarbons and trichloroethylene in the wind tunnel. Trichloroethylene levels at several locations in the plant room (near pump seals, etc.) will also be monitored. Sample locations and cycle times would be finalized during detail design.

The high hydrocarbons alarm is interlocked with the fan to shut it down when high levels of hydrocarbons are detected. The alarms associated with the remaining gases will warn the operator of a dangerous condition by means of audible and visual alarm displays in the Control Rooms.

3.10 Special Test Systems

3.10.1 Humidity Control System

The humidity control system is the most basic of the special test systems available for the dynamic facility, and is proposed as a standard feature for all three Configurations. In addition to the obvious function of generating extremely high humidity conditions for special investigations,the system also serves to maintain tunnel air humidity at constant nominal values by replacing moisture losses due to shell leakage and condensation on the main heat exchanger. The latter condition is unavoidable when the tunnel is operating at high humidity and heavy cooling system load levels. For the special case of chassis dynamometer testing (Configuration 3), the humidity control system also serves to replace moisture lost through the test vehicle's combustion air draw.

The two basic elements of the humidity control system will be a steam grid located in the second crossleg and a steam generator located in the Plant Room (Support Building 2). The steam grid will consist of a 5x5 manifold of stainless steel tubing, with supply orifices located at regular intervals. The steam generator will be sized for approximately 900 kg/h (600 kW) output and will be connected to the steam grid by an above-ground, insulated, stainless-steel delivery line (fitted with the necessary traps, drains, and manual shut-off valves).

System control will be effected by the Facility Support System (see Section 3.9) by means of a controllable on-off steam valve. The system will be capable of creating relative humidites of up to 10°C depressed dewpoint temperature (relative to tunnel air ambient) for tunnel air temperatures above 0°C. Progressively degraded performance will occur for temperatures lower than this. High-humidity investigations include carburetor icing, sensitivity of electrical systems, and cab comfort evaluations. Medical research activities will be concerned with the cumulative effect of temperature, humidity and windspeed on personnel comfort levels and efficiency.

3.10.2 Rain and Freezing Rain Simulation

The inclusion of rain and freezing rain simulation capabilities as part of Facility Configurations 2 and 3 must be considered of

secondary importance, particularly for the case of rain simulation. Little specific interest was uncovered during the user survey for a normal (i.e. above freezing) rain simulation. The low-speed nature of the proposed facility would limit the applications of such a simulation capability to leak and infiltration tests, plus windshield wiper evaluations. These will probably be best carried out using a single-nozzle, pressurized water delivery system with manual positioning. Drains will be provided in the floor of the new test section to permit removal of accumulated water. Similar drains already exist in the floor of the NRC CEF test chamber. A booster pump for the water supply will be located in the basement of Support Building 1. In view of the limited water supply source for the site (i.e. well), a small water storage tank of approximately 20,000 ℓ capacity will be provided at ground level alongside Support Building 1.

Freezing rain and icing simulation presents a much more complex proposition. General options are for 'global' or localized sources, the latter being the recommended approach. For a 'global' source, the approach would be to install a 5 x 5 spray rake across the settling chamber, immediately upstream of the contraction. Distributed across the resultant grid would be approximately 40 two-fluid- atomizer spray nozzles (commercially available). Each nozzle would mix pressurized water (from the center orifice) with pressurized air (from the outer annular orifice). Both air and water distribution manifolds would be housed within aerofoil-section aluminum rake covers. Also carried within the rake cover would be a heating tube manifold, supplied with steam from the facility's steam generator. Provision of this local heat source is required to prevent freeze-up of the spray nozzles.

The 'global' approach would require a distilled water source (using the same storage tank as the rain simulation system) with in-line filtering. The 'clean' water source is necessary to avoid long-term fouling of the nozzles by mineral scale buildup. On-line water demineralizing would not be recommended, due to the likelihood of infrequent use of the overall system. The rain simulation system's booster pump would be required to generate water supply pressures of approximately 1.5 atmospheres in the delivery manifold. For droplet sizes of about 200 microns, a water supply rate of about 15 ℓ/min. would be required at maximum facility air flow rates. This would produce a freezing rain 'density' of about 0.3 g/m^3 of tunnel air

at maximum tunnel air velocity. To provide the full range of droplet sizes considered representative of freezing rain/drizzle conditions, water supply rates of up to 100 ℓ/min. would be necessary. A 200 kW air compressor would be required.

The triple-manifold (water/air/steam) spray rake described above would likely cost well in excess of $250,000. installed (with associated compressor, supply lines, and controls) and would ideally be removable when not in use. Although the 'global' approach would certainly provide the most realistic simulation for freezing rain studies, it must be emphasized that it would also create significant problems in the remainder of the air circuit design - specifically, ice deposition on internal components (turning vanes, flow screens and the main heat exchanger). For this reason, 'global' icing studies are generally restricted to single-purpose tunnels (e.g. NRC's low and high-speed icing tunnels, and the NASA Lewis tunnel in Cleveland). In those designs, special measures such as heated (or the complete absence of) turning vanes, glycol sprays, and secondary settling chambers (in the first crossleg) are variously used to remove the majority of the air-borne ice crystals before they create build-up problems. These tunnel designs, and the measurement techniques employed therein, are well documented in Reference 17, along with a number of additional sources for detailed reference.

In the case at hand, it is felt that the inclusion of a 'global' freezing rain simulation capability is inappropriate for reasons of cost and projected compromises in overall air circuit design. In addition, the proximity of NRC's two dedicated icing tunnels in the Ottawa region suggests an unwarranted redundancy. For these reasons, a local-source approach is recommended, using existing NRC equipment.

This equipment consists of portable spray rakes of a concentric-ring/radial-spoke configuration. Maximum diameter of the rake is approximately 1.5 m. Operating principle is again based on compressed-air/atomized-water mixing, but at considerably reduced supply rates. A 10 kW air compressor (mounted on an independent foundation plate) with associated plenum and filter will be located in a sound-absorbing enclosure in the basement of Support Building 1. Distilled water supply will be from the outdoor storage tank (located in a heated shed), with booster pump and filtration as discussed earlier. Provision for heating of both the compressed air

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and water supply will be made as required using the facility's steam generator or, alternatively, electric heaters.

The portable spray rakes will be manually positioned as required to direct the spray into the airstream in such a fashion that the zone of interest on the test item is properly covered. It must be stressed that this simulation technique is not capable of generating the dendritic-type crystal typical of snow (dry or wet). There are no satisfactory means available for artificially generating dendritic snow crystals for facility testing. As such, any attempts to study snow ingestion/clogging problems will require the development of a snow injection scheme (probably by a combined conveyor belt/forced-air delivery system) using snow of the appropriate texture trucked in during the winter. Such a scheme can probably be developed, but is considered to be beyond the scope of this study. Running the facility in this mode will probably require open-circuit testing (i.e. opening the main vehicle access door at Corner No. 1) in order to prevent the aforementioned fouling problem of internal air circuit components.

3.10.3 Solar Simulation System

The capability for accurately simulating the thermal loading imposed by solar light on passenger compartment/operator cab air conditioning systems (or on test volunteers during medical research investigations) has been incorporated as a feature of Facility Configurations 2 and 3. At the present time, the most accurate simulation of solar heating (i.e. correct spectral distribution of energy content) is provided by a compact-source iodide (arc discharge) lamp, typically rated a 1 kW power draw per unit.

The proposed system provides for a bank of 200 of these lamps, built into the slats of the slotted-wall liner in the new test section (see DSMA Drawings No. E 4027-06 and E 4027-07). The lamp bank will be located on the outside wall only, with spacing geometry and overall coverage commensurate with the requirements for illuminating a target area of approximately 7.0 m by 3.5 m (i.e. 24.5 m^2). It must be noted that the installed cost of these lamps (including associated wiring, transformers, and controls) is in excess of $1,300. per unit; hence, the provision of a lamp bank sufficient to carry out tests on a rail passenger vehicle over its full length would be extremely expensive. The proposed configuration could only

be used for tests on these vehicles if part of the vehicle length was blocked off.

The system will be designed and configured to provide a target-plane intensity of approximately 1.0 kW/m^2, with spatial uniformity to ±10%. Depending on final decisions concerning the range of target sizes and shapes to be accommodated, it may be necessary to locate some or all of the lamp bank in the ceiling slats. Lamp mounting in the slat assemblies should provide an essentially flush fit with the exposed slat surface in order to minimize shrouding and aerodynamic disturbances. Removable fine-wire-mesh covers will be fitted over each lamp pocket to contain glass fragments in the event of bulb breakage.

The CSI-type lamps are relatively sensitive to heat build-up in terms of both lamp life and restrike (start-up) performance. With this in mind, the fully-shrouded mounting location for the lamps within the slat assemblies will require the provision of a dedicated, forced-air cooling system to duct outside air along the length of each of the slats involved. A centrifugal blower will be fitted for this purpose, with supply and exhaust manifolds provided at the upstream and downstream ends of the slats. Cooling air will be exhausted to the outside.

Power supply and control for the lamp bank will be carried out in conjunction with 8 "Regavolt" type variable-output transformers, located in the basement of Support Building 1. Each of the lamps must be independently wired for basic power supply and for ignition power supply. A strip-type ammeter and a circuit breaker will be fitted for each lamp circuit. The overall control function for the lamp bank will be carried out by the Facility Support System. Lamp intensity will be controllable over the range from 100% to approximately 60% of full supply voltage. The lamps will begin to self-extinguish for power levels beneath the latter figure. A portable radiation intensity sensor will be used to carry out initial calibration and periodic check procedures.

It should be noted that the heat build-up problem mentioned earlier may also force the use of special MICC-type (mineral-insulated, copper-core) wiring for the lamp circuits in the immediate region of the slat assemblies. Should this be the case, the cost for the entire solar simulation system is likely to increase by at least $30,000.

3.10.4 Dynamometer System

Facility Configuration 3 is based on the addition of a chassis dynamometer to the new test section. As has been discussed at the beginning of this section, this provision will be for highway-type and off-highway vehicles, but not for rail vehicles. A maximum absorption capability of approximately 375 kW was assessed as being adequate to accommodate most of the target group. Basic choices centre on the type of absorber (DC machine, eddy current or hydrokinetic) to be used, the extent of simulation capability required (motoring, inertia simulation, drive cycle capability, etc.), and the extent of drive train configurations to be accommodated (e.g. front-wheel-drive, rear-wheel-drive, four-wheel- drive, tandem rear axle drive, six-wheel-drive, track drive).

The issues of absorber type and simulation capability are to a large extent interrelated. Both the DC and EC (eddy current) absorbers can be specified to permit drive cycle simulations - that is, the ability to simulate a prescribed time history of vehicle speed and engine load, including coastdown. The hydrokinetic absorber (water brake) does not permit this simulation. DC machines (and to a lesser extent EC machines) are highly accurate (speed and torque to ±0.5% F.S., or better) and repeatable, whereas the hydrokinetic absorbers are highly repeatable but not as accurate in the absolute sense. All three types are capable of providing vehicle inertia simulation, the former two using combined electrical and mechanical components while the water brake relies totally on mechanical simulation (rotating, interchangeable flywheels). All three types are capable of constant-speed or constant-torque measurement modes, although the EC and hydrokinetic types are somewhat limited in terms of high torque at low speed by virtue of their fundamental absorption principles.

In a cost-no-object application for research and development dedicated to powertrain applications, the DC machine is the immediate choice. For chassis dynamometer applications, however, the DC specification dictates custom design at high cost, since no off-the-shelf package units are available. Installed cost for a single-roll dynamometer (i.e. capable of accepting two-wheel-drive vehicles only) of this type and for the 375 kW power requirement could easily exceed 500,000. For a highly-versatile configuration capable of accommodating the full range of drive train configurations listed at

the outset, a DC-type dynamometer with three rolls and adjustable wheelbase would easily exceed $1,000,000. in cost.

Bare EC absorbers offer noteworthy savings relative to DC machines (perhaps 50% or more), although much of this is lost when a supplementary drive motor is added to provide motoring capability. Once again, EC-type chassis dynamometers are custom designs, and savings in the bare absorber unit are likely to be completely overshadowed by the cost of the rolls and supporting structure.

Finally, the use of DC or EC absorbers generally assumes a requirement for drive cycle simulations in order to justify the high accuracy and cost. Unfortunately the drive cycle application implicitly requires a capability on the part of the fan drive to accurately track the variable vehicle speed. Furthermore, the variable engine load (and consequently, heat rejection to tunnel air) and fan speed require significant reserve capacity on the part of the tunnel cooling system in order to maintain reasonable air temperature stability during transient vehicle operations. This, of course, becomes critical if there is a requirement to carry out drive cycles at low air temperatures.

Bearing in mind all of the above considerations, it is felt that the requirements for chassis dynamometer testing in the dynamic facility are best answered by the use of a hydrokinetic absorber unit. This will permit trend and comparative studies with good repeatability, although with some degradation in absolute accuracy.

The assembly proposed is an off-the-shelf package manufactured by Clayton - AESI (U.S. - based) as their Model HCT 200/400/200. It consists of three separate roll-pairs, each with its own absorber unit and inertia flywheel system. Capability is provided for the accommodation of all types of drive configurations listed earlier (except tracked vehicles).

The leading and trailing assemblies will be supported on crane rails such that their locations relative to the fixed center assembly can be adjusted for various wheelbases. All rolls assemblies will be recessed into a shallow floor pit at the upstream end of the new test section, such that the test vehicle will sit essentially at floor level when positioned on the rolls. Wheelbase adjustment is

carried out manually. Removable steel-plate cover panels (segmented) will be provided to cover the pit openings between the rolls assemblies. When necessary, the rolls assemblies can be completely removed from the test section using a forklift truck. Maximum front-to-rear wheelbase provision has little impact on total installed cost and should be selected during the detail design phase.

The absorber units for the leading, central and trailing rolls assemblies are rated at 150, 300 and 150 kW respectively. Each unit is capable of independent control and has its own speed/load read-out. For multi-axle drive configurations, the load read-outs will be added for a total value. The load/speed curve for the 150 kW absorber is shown in Figure 17. All units are capable of absorbing their full rated load for speeds above 80 km/hr. Maximum speed capability is nominally 195 km/h. The minimum control curve extends from 0 kW at 0 km/h to 4.5 kW at 100 km/h. The interface of the chassis dynamometer with the Facility Support System has already been addressed in Section 3.9.

Each rolls assembly is fitted with air-operated brakes and is rated at 11340 kg axle load. The inertia flywheel systems are belt-driven and declutchable. In standard form, each unit's inertia is equivalent to a maximum 1815 kg vehicle weight. Adjustments are carried out manually by the addition or subtraction of weights prior to test.

This study will not address in great detail the provision of chassis dynamometer test capability for tracked vehicles. It is feasible for such a provision to be made, but only on the basis of a discrete apparatus dedicated to the task. Such an apparatus could be implemented in the facility on a roll-in/roll-out basis. A permanent installation would severely compromise the layout of the new test section and is not considered an effective solution. It is possible that the removable assembly could be designed to use the Clayton/-AESI absorber units, thus sparing a duplication of cost in that regard. Further consideration for a tracked-vehicle chassis dynamometer would rest primarily on the degree of importance attached by prospective test clients (primarily military) for climatic testing of such units under powered-up conditions. The proposed dynamometer system is felt to provide the most cost-effective solution for accommodating the wide variety of drivetrain configurations likely to be of interest.

3.10.5 Combustion Air Make-up/Dehumidification System

Specific to the dynamometer testing provision in Facility Configuration 3 is the mandatory addition of the combustion air make-up/dehumidification system (hereafter referred to simply as the make-up air system).

Tunnel air consumed by the test vehicle must be made up with a similar amount of fresh air. Simply admitting raw ambient air, however, would eventually cause severe icing of the main heat exchanger. This initially causes loss of uniformity in temperature and velocity distribution, and ultimately forces shutdowns for defrosting. The make-up air must, therefore, be dehumidified at least to the required dewpoint of the air in the tunnel. To contend with ice formation in the dehumidifying system, two separate and parallel units will be required, with one unit operating while the other unit is defrosting.

The air make-up/dehumidifier system is shown schematically on DSMA Drawing No. E 4027-08. The unit will consist of an inlet filter, fan, high and low-temperature cooling coils, dampers, heaters, and an insulated casing. Ancillary equipment will include a two-stage condensing unit and a defrost control.

Air drawn in from outside the tunnel will pass through the high-temperature cooling coil (HX 105). The brine temperature entering this coil will be maintained at 0°C in order to dehumidify the air to the greatest extent possible without coil frosting. The brine for the cooling coil (HX 105) will be taken from the main cooling system by means of an above-ground thermally-insulated supply/return line originating at the main heat exchanger. As discussed in Section 3.3, the air make-up system will be housed in Support Building 3, immediately upstream of Corner No. 1.

The partially cooled and dehumidified air will then pass on through one of the low-temperature coils (HX 106, 107). Here, it will be further cooled to the required dew point temperature, and the remaining water vapour will condense out and freeze on the surface of the coil.

A separate refrigeration unit will be required for cooling the low-temperature coils. This will consist of a two-stage reciprocating

compressor, a water-cooled condenser, a liquid suction heat exchanger, and controls. The refrigerant that condenses in the unit will be delivered to the low-temperature coils; the resulting refrigerant vapour will be drawn off by the compressor (during detailed design, it may prove to be more economical to supply the low-temperature coils with brine from the main cooling system and delete the separate condensing unit entirely). The fully cooled and dehumidified air will then be ducted to the main air circuit, entering the air circuit downstream of test section.

After some period of operation, frosting of the in-service low-temperature coil will start to interfere with heat transfer. When this occurs, the air stream will be diverted to the stand-by low-temperature coil while the first coil undergoes a defrost operation. This transfer and defrost process will be affected by damper positioning and electric heaters, under the control of a timing circuit. The overall control of the air make-up system will be carried out automatically by the Facility Support System, as discussed in Section 3.9.

3.10.6 Engine Exhaust Extraction System

This system (hereafter referred to as simply the extraction system) is a mandatory provision for the chassis dynamometer tests to be carried out in Configuration 3. The purpose of the extraction system is twofold: to prevent fouling of the tunnel air by the engine exhaust gases and to reduce the thermal load on the tunnel cooling system created by engine exhaust gas thermal energy.

The principle of operation for the extraction system involves the provision of a sealed passage from the vehicle's exhaust pipe to a primary facility exhaust manifold located along the inside wall of the new test section plenum. A variable-speed fan will be employed in the primary manifold to draw fresh air from outside the facility, mix it with the engine exhaust and then deliver the mixture back to the outdoors. The fan location employed in this configuration significantly reduces operating temperatures for the drive motor (with consequent benefits in reliability and original cost) by mixing hot exhaust gases with cooling air before they reach the fan location.

The Facility Support System (see Section 3.9) will control the fan speed in such a fashion as to minimize backpressure on the engine

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(less than 13 mm H_2O between vehicle exhaust pipe and test section ambient) for the full range of engine load/speed conditions. Appropriate pressure sensors will be provided at the exhaust pipe connection and within the test section to permit this control function.

A flexible pipe will provide the connection from the vehicle exhaust pipe to the facility primary exhaust manifold. Provision will be made for a leak-free connection at the vehicle in order to minimize requirements for the Combustion Air Make-up System (see Section 3.10.6). In view of the wide range of vehicle configurations anticipated for the proposed facility, the primary exhaust manifold will be provided with several capped connection points for flex-pipe hook-up. Several different adaptors will be required for the flex-pipe/vehicle connection for the same reason. All pipes employed in the system will be thermally insulated and constructed of corrosion-proof materials.

3.10.7 Tunnel Purge System

The tunnel air purge system is an extension of the facility's Safety System (see Section 3.9), and is considered at this stage of facility planning to be appropriate to Facility Configuration 3 only (i.e. dynamometer testing). The purpose of this system will be to provide emergency purge ventilation of the air circuit (principally in the test section) in the event of contamination by fuel spills. The system will consist of three exhaust fans drawing the contaminated tunnel air out of the tunnel through floor level extraction ducts placed along the length of the test section. A fourth fan and duct will service the dynamometer floor pit.

The fans will all have explosion-proof drive motors. Each of the extraction ducts will have a power-actuated closure flap, normally set in the closed position. Actuation of the system will be automatic, with provision for manual override from either of the control rooms, and will simultaneously cause shut-down of the main fan drive and the test vehicle engine. Actuation will be linked to the gas detection unit in the facility's Safety System. If dynamometer tests are projected for vehicles using lighter-than-air fuels, the extraction duct system will have to be made bi-level, such that it can draw from either the floor or the ceiling. Drains will be provided in the dynamometer floor pit to prevent accumulation of liquid fuel after spills.

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3.11 Electrical Power Supply and Distribution

3.11.1 Distribution

The proposed basic electrical distribution scheme is illustrated in DSMA Drawing No. E 4027-09. The scheme remains essentially the same regardless of the Facility Configuration involved, although the rated capacities for various sub-elements differ in most cases.

The distribution system begins with a large main substation for stepdown of main supply from 27.6 kv to 4.16 kv. This substation will be located outdoors at the east end of Support Building 2 (see DSMA Drawing No. E 4027-03). Rated capacity will be 7500 kva for Facility Configurations 1 and 2, or 10,000 kva for Facility Configuration 3. The Electrical Room in that building will contain two transformer vaults housing the 3750 kva fan transformer and the 2500 kva 4.16 kv/600 v unit substation. 4.16 kv and 600 v switchgear will also be located in the Electrical Room.

Due to their high loads, the high-stage compressors of the refrigeration plant are supplied at the 4.16 kv level, with dedicated switchgear. The fan drive is supplied with variable DC power by a dedicated convertor. The remainder of the facility loads, including the low-stage refrigeration compressors, are supplied with 600 v 3-phase power and are split into three subsystems: 1) general motor control circuits (MCC's) and power distribution (building and special test system loads); 2) fan auxiliaries MCC's (lubrication and cooling systems); and 3) refrigeration low-stage compressors and general MCC's (including the make-up air system in Facility Configuration 3). Fan and 600 v distribution cabling will be carried to the appropriate end hardware by buried cable conduits.

3.11.2 Supply

The exact definition of operating power requirements for the various Facility Configurations requires extensive development of operating scenarios for various testing set-ups and is appropriate only to the detail design phase. It should be noted that a summation of the distribution capacities for all of the subsystems shown in the distribution schematic will result in somewhat exaggerated supply requirements; not all of the loads in a given subsystem will be operating at the same time. A preliminary estimate of maximum total

loads on the grid is given for each Facility Configuration as follows:

Facility Configuration 1: 6.63 MW
Facility Configuration 2: 6.63 MW
Facility Configuration 3: 6.92 MW

These loads are obviously significant, not only in terms of facility operating costs, but also in terms of available supply from the local utility. Several discussions were held with Gloucester Hydro who represent the most likely electrical power supply source (direct supply from Ontario Hydro being the only other alternative). Given the massive draw and the projected usage patterns (i.e. intermittent, relatively short duration, and short-term advance notice), Gloucester's representative said that the facility would constitute a less-than-desirable customer although arrangements were not ruled out entirely. Extensive planning and discussions in this regard will be mandatory during the next planning stage.

Regarding physical power feed provisions, the NRC Railway Laboratory is currently served from the Gloucester grid by a short-length 8.32 kv line (privately owned by NRC) which originates approximately 1 km north of the site along the CP Rail mainline trackage (see Figure 19). This feeder follows the mainline trackage to the lab site, and then parallels the NRC spur line up to the existing substation at the south-west corner of the Building U89. Costs for upgrade of the private 8.32 kv feeder to the recommended 27.6 kv level would have to be entirely absorbed within the facility acquisition cost.

The NRC private line ties into a Gloucester 8.32 kv feeder which travels approximately 1.4 km west and north to Gloucester's Uplands Main Substation. This Gloucester feeder would also have to be upgraded to the 27.6 kv level and additionally a new 115 kv/27.6 kv substation would have to be built. Alternatively, Gloucester's nearest existing 27.6 kv substation (Hawthorne Road District Substation) lies 5.6 km to the south-east of the Railway Laboratory. Sourcing power from this point would remove the cost of a new substation at the expense of a new, dedicated 27.6 kv feeder of between 5.6 km and 8 km length (depending on route). Exact costing of either of these alternatives is beyond the scope of this study and inadvisable at such an early planning stage. A very approximate estimate of $250,000. (Reference 22) has been made in conjunction

with Gloucester Hydro and will be considered indicative of either option. It must be assumed at this stage of planning that the full cost of the line upgrade will have to be absorbed within the facility acquisition cost.

3.12 Site Integration

Unlike construction of a 'stand-alone' dynamic facility, the choice of the add-on configuration dictates considerable care in terms of site integration. This will include considerations of general services (water, sewage), access and parking, land availability, re-location of existing equipment where necessary and drainage provisions. These aspects have all been included in the facility acquisition costs to follow in Section 6, and will be discussed briefly here.

a) Site Clearance and Preparation

Approximately 1000 m^2 of treed area will need to be cleared to accommodate the general site, relocated leaching field, new rail spur, and test section liner storage pad. A moderate amount of cut and fill will be necessary to establish level and consistent elevations over the tunnel and support building construction zones. Site drainage during construction may be troublesome (high water table).

b) Access and Parking

The second crossleg of the return circuit will unavoidably intrude into the existing parking lot between the new CEF and Building U-89's administration/lab wing. The proposed layout minimizes this intrusion to the maximum extent commensurate with airline design requirements, but will nevertheless reduce the pavement width between the wind tunnel shell and Building U-89 to about 7 m. This will dictate parallel parking of delivery trucks for loading/unloading activities at the rear of U-89. A new 7000 m^2 parking lot will be required at the north end of Building U-89. In addition, a new service road will be required as shown in DSMA Drawing No. E4027-03 around the north and east sides of the dynamic facility complex. The existing service road paralleling the south side of the CEF will remain unchanged.

c) Sewage

The proposed facility layout will place the fan leg of the wind tunnel and Support Building 2 directly over top of the existing leaching field. It will be necessary to relocate that leaching field approximately 20 m north of its present location, although no significant increase in its size will be required. The existing septic tank will not require any changes.

d) Water Supply

The concrete/insulated floor section of the wind tunnel's first crossleg will lie directly over top of the CEF's existing well site. In addition, the increased demands forced by the dynamic facility's cooling system will require a much greater supply rate. It will be necessary to fill the existing well and create at least one new well to the east of the complex. Supply line extensions will be required to all new support buildings. Make-up water requirements for the new cooling system's evaporative condensor are estimated at between 215 and 325 ℓ/min., depending upon the facility configuration.

e) Rail Spur Re-Alignment

In addition to the new spur line required to serve the test section liner storage pad, it will be necessary to re-align the existing rail spur serving the CEF. Purpose of this re-alignment will be to move the final curve in the spur far enough away from the vehicle access door at Corner 1 to assure that rail vehicles will be aligned parallel to the tunnel centerline at the point of entry. Without this change, interference with the door frame will occur when moving rail vehicles in or out of the tunnel. Re-alignment costs will assume all-new trackage, although some economies may be realized if existing rail can be re-used.

f) Static Facility Condensor Pad Relocation

The CEF's condensor location at the north-west building corner will have to be moved approximately 15 m to the east of its present site in order to permit construction of Support Building 1. This will necessitate demolition of the existing pad and

placement of a new one, in addition to relocation of the condensor and extension of its supply/return lines.

g) Main Substation Transformer Pad

A concrete support pad, along with a gravelled site and surrounding fence, will be required at the east end of Support Building 2.

h) Site Drainage

A new culvert will be required, running east-west between the wind tunnel fan leg and Support Building 2, and extending east out to the forested area. It will also be necessary to extend the existing culverts at the east end of the CEF by several metres in order to tie in with the new culvert. Finally, a new manhole and culvert will be necessary to drain the new east-west service road alongside Support Building 2.

i) Electrical Supply/Distribution

Although this issue has been treated in some detail in Section 3.1i, there are some additional considerations which hinge on the choice of power supply origin (i.e. upgrade the existing 8.32 kv feeder or bring in a new dedicated 27.6 kv supply from the Hawthorne Road Substation). In the former case, the existing 8.32 kv/600v substation at the south-west corner of the U-89 buildings would become obsolete. It would be advisable at that point to backfeed the existing NRC Railway Laboratory buildings from the new dynamic facility using the 600v distribution conduit already in place between the CEF and the east corner of the curved track simulator building. Alternatively, if a dedicated 27.6 kv feeder is provided for the dynamic facility substation, it would be economical to keep the dynamic facility distribution system entirely separate from the existing NRC system. This would result, of course, in the site being served by two separate feeders and unit substations (i.e. an 8.32 kv feeder and a 27.6 kv feeder).

j) Miscellaneous

Miscellaneous requirements include:

- relocation of about 80 m of existing perimeter fence
- 30 m of new perimeter fencing
- wind tunnel lightning protection
- general internal lighting for the wind tunnel
- general outdoor lighting for roadways, parking lot and buildings

4. PROPOSED FACILITY PERFORMANCE

Unless otherwise noted, the appearance of a single value for a given item indicates that the same performance will be achieved for all three facility configurations.

4.1 Airflow

a) Maximum Speed (measured at nozzle exit plane, -30°C)

No. 1. 90 km/h (windwipe speed: 225 km/h for 60% blockage
145 km/h for 38% blockage)

No. 2. 100 km/h (higher-speed, windwipe tests optional)

No. 3. 100 km/h (higher-speed, windwipe test optional)

b) Flow Quality

No. 1. Commensurate with windwipe studies of long test bodies only. Severely degraded simulation at or near front and back ends of test body. Full capability for test objects of less than 10% blockage, using correction factors.

No. 2. Commensurate with climatic studies of all test bodies up to 60% blockage. Higher-speed, windwipe studies also available.

No. 3. See 2.

c) Airline Specifications

Nozzle Area	24.4 m^2
Nozzle Aspect Ratio	0.86
Contraction Ratio	2.4:1
Test Section Height	5.33 m
Test Section Width	4.57 m

d) Fan Specifications

Diameter	5.0 m
Hub: Tip Diameter Ratio	0.5:1
Maximum Speed	540 rpm
Turndown Ratio	10:1
Speed Control (% of full-scale)	±1.0%
Fan Shaft Power (for solid-wall testing of articles with 60% blockage)	2.28 MW
Drive	DC/SCR

4.2 Temperature and Humidity

a) Test Temperature (at test section entry)

Minimum	-30°C
Maximum	+50°C
Uniformity (std. deviation)	1°C

b) Pulldown Times (minimum)

+30°C to -30°C	6 hr
+30°C to -40°C	8 hr
+30°C to -50°C	12 hr

c) Maximum Dew Point Depression

- measured relative to tunnel air ambient	-10°C

d) Dew Point Accuracy — manual control

e) Refrigeration Plant

Size	1. 2.64 MW
	2. 2.64 MW
	3. 3.14 MW
Brine	Trichloroethylene
Refrigerant	Fluorinated Hydrocarbon
Cooling Water System	Evaporative Condensor

4.3 Dynamometer

(Facility Configuration 3 only)

Maximum Speed (nominal)	195 km/h
Maximum Absorbing Power	Front: 150 kW Centre: 300 kW Rear: 150 kW
Absorber Type	Hydrokinetic
Inertia Simulation (maximum)	Flywheels, 1815 kg/roll
Maximum Axle Load (individual)	11340 kg
Wheelbase Range	as required
Maximum Vehicle Track	2.54 m
Rolls Diameter	220 mm
Operating Modes	- constant speed - constant torque
Vehicle Types	- front wheel drive - rear wheel drive - tandem axle drive - four wheel drive - six wheel drive - no tracked vehicles

4.4 Special Test Systems

Refer to Table 2 and Section 3.10.

5. OPERATING CONSIDERATIONS

The operation of the dynamic facility is expected to be an intermittent activity, at least during the initial few years of the facility's operating life. Since the dynamic facility and the NRC CEF would share the same test section, any staff or resources which are totally dedicated to the operation of the CEF should, for the most part, be available for the operation of the dynamic circuit.

Due to the additional capabilities of the dynamic facility, however, its operation would require some specialized staff and would place additional demands on the resources of the operating organization.

This section examines some of the operating assumptions, and attempts to develop realistic operating scenarios as a basis for cost/benefit analysis in the following section.

5.1 Test Sequence

The testing process in a large dynamic CCTF involves a number of steps. The scope and range of activities is dictated by, among other things, the objectives of the researcher, the sophistication of the test programme, the operating demands of the test facility and the degree of complexity of the subsequent data analysis and report preparation. In general terms, the tests which are appropriate to a large dynamic CCTF rank high on all of the scales mentioned above. Specifically, the following activities will probably be present for most tests:

5.2 Test Specification

Prior to expanding any effort on the implementation of a test programme, considerable effort must go into defining the objectives, methodology, logistics, test format and criteria for success. This activity is normally carried out by the organization which is commissioning the test programme. In the area of climatic simulation, however, effective test design and specification requires specialized knowledge which private companies or client organizations may

not possess, (the User Survey discovered, for example, that 57 percent of all respondents are only occasionally involved in climatic research and development testing). It is worth noting that the Consultants have encountered this dilemma with corporate climatic test facility clients. In the notable case of a major automobile manufacturer, a climatic wind tunnel was booked for only 30% usage immediately after commissioning, yet within one year it was being used intensively on a two-shifts-per-day basis.

In many cases where industrial organizations wish to conduct test programmes, they will require the services of a specialist organization in order to get started. NRC have fulfilled this role in the past in this field and are the logical choice to continue doing so with the facility under study. During the interview process, several industrial organizations indicated a strong preference for NRC's involvement, primarily to provide those services which the industrial organization was not equipped to perform.

The need to provide these support services will directly influence the amount of staff allocated for supporting the dynamic facility.

5.3 Test Set-up

Preparation of the test objects for a dynamic facility of this scale will require considerable time and effort. Instrumenting a rail car for heat balance tests may require the placement of up to 200 temperature, wind velocity, air pressure and assorted other sensors. Depending on the work force assigned to the task, it may take one or two weeks of effort to complete the preparations of the vehicle. While much of this work can proceed outside the test facility itself, several days must be spent connecting the instruments to data acquisition devices and completing the preparations. This is time during which the test facility is unavailable for other work. Again, NRC staff will probably be required to perform these tasks for many of the potential clients.

5.4 Temperature Pulldown

The refrigeration plant for the dynamic CCTF has been sized to permit operation at the minimum operating temperature of -30°C, with the fan operating at maximum speed. Given this refrigeration system, a test facility with the shell mass of the one under study

cannot be cooled to -30°C in less than 6 hours. The cooling process will require the circuit to operate in an optimal cooling mode until all parts of the circuit, including the test object and the shell, have stabilized at the desired test temperature.

The pulldown process is an exponential one. The cooldown rate is rapid at high temperatures, but is much slower at low temperatures. In addition, the heat generated by the fan increases as the cube of the air velocity. In order to achieve efficient cool down, the optimal cooling programme will probably involve operating the refrigeration system at close to full capacity while running the fan at a speed which is just sufficient to achieve adequate air circulation and mixing. The thermal time constant of the test article mass must also be considered when evaluating pulldown performance.

Once the circuit has reached the desired temperature, the appropriate wind velocity would be generated and held until the facility had again stabilized. The total procedure will probably consume at least a full working shift, and perhaps two. This scenario is consistent with initial start up of a heat balance test which is to simulate minimum operating temperature and maximum vehicle speed.

Initial conditions for other, less demanding tests may be approached by different means. Precise cooldown procedures would be developed during the initial, breaking-in stages of facility operation. During that time, the operating information gathered by the facility control computer would be analyzed to determine the most cost-effective approaches. Implementation of the NRC CEF's refrigeration plant for overnight intermediate temperature hold has been discussed in Section 3.8 as one strategy.

5.5 Test Programme

The execution of the test programme will vary tremendously, depending on the nature of the research or test being conducted. In particular, there will be substantial differences in the objectives and methods of product development testing, as opposed to more general research. The rail car heat balance tests and ventilator location tests will probably be closely related to product development.

Due to the diversity of possible uses of the dynamic facility, it is impossible to define a "typical" testing programme. It is likely,

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however, that users of the CCTF will want to conduct all relevant tests at one time to minimize the costs of the other steps associated with the testing cycle. Most test programmes, therefore, will probably last for at least several days and many will last for weeks. During this time, the CCTF may be cycled through a range of temperature and wind speed settings. Operational efficiency will increase as the facility operators gain experience in the use of the circuit and with the specific requirements of the tests or research being conducted.

Over time, some tests should become well defined, and optimized operating procedures will be developed to enable these tests to be conducted as efficiently as possible. At the moment, however, no such body of experience exists in North America as applied to large-scale dynamic controlled-climate testing. Initially, therefore, testing will probably be dominated by a degree of trial and error.

In addition to the test programmes identified for the railway sector, possible product development testing for other large equipment manufacturers will likely undergo a similar evolution. As NRC and clients gain more experience with the use of the dynamic facility, the operational efficiency should increase. Gains are most likely in the areas of test scheduling, operating experience and automation.

1. Test Scheduling - CCTF efficiency will increase when tests become better standardized. The scheduling of testing programmes will take into account possibilities for sharing support staff among similar tests and possible economies of scale. Since there is no existing facility of this type, most of these lessons will be learned only through experience.

2. Operator Experience - As the operators become more experienced, they will be better able to manage the operation of the CCTF. Optimal procedures for moving from one set of test conditions to another will be developed. An understanding of what constitutes sufficient stabilization of the conditions for a given type of test or test item will also be achieved.

3. Automation - The CCTF design includes a sophisticated and flexible computer system for monitoring, control, data acquisition and data management. It is likely that early testing programmes will rely heavily on human observation. Once testing

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experience has been gained, tests such as the heat balance investigation will rely heavily on numerical analysis of data and thus are easily adaptable to fully automated operation.

It is likely that any form of repetitive testing programme will be subject to a very steep learning curve. On the other hand, general research will probably be less subject to such improvements, except for the gains made in understanding the facility operation.

The CCTF's unique capabilities provide substantial opportunities for NRC and other organizations to conduct more fundamental investigations of cold weather phenomena. While several ideas have been put forth already (e.g. simulation of snow formation by utilizing the long test section and high wind velocity), many more ideas will develop as potential researchers become aware of the facility and its capabilities.

Investigative research will not be subject to the same steep learning curve as product development testing since the work is, by definition, innovative and not as amenable to automation.

5.6 Test Cleanup

Once the testing programme has been completed, the test object will have to be dismounted and the support apparatus cleared away. Depending on the complexity of the test setup, anywhere from a day to a week will be necessary to complete the removal of the test object.

5.7 Data Reduction and Report Generation

Data analysis requirements will vary widely among tests. In some tests, the data will be largely subjective characterizations of visually observed phenomena. This may be particularly true of basic research projects.

At the other end of the scale, some tests will require the acquisition, reduction and analysis of large amounts of data from instrumentation. In either case, the interpretation process requires the involvement of experienced test engineers and researchers.

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5.8 Summary

The operation of the dynamic CCTF will evolve over the intial few years. No one knows what the ultimate test activity mix will be, nor how the test facility operator will precisely conduct testing programmes. What does seem likely is that the testing procedures will be subject to a substantial learning curve and that any repetitive testing should become more and more efficient. This is relevant to subsequent cost estimates, particularly as they project further into the CCTF's operating life.

6. COST ESTIMATES

6.1 General

Budget cost estimates have been developed for the three facility configurations described in Section 3. These cost estimates are broken down initially into six broad categories, as follows:

1. Site Preparation and Services
2. Support Buildings
3. Wind Tunnel Hardware
4. Electrical Power Supply/Distribution
5. Architectural Services
6. Engineering, Programme Management, and Constructor Charges

For Categories 1-4, costs have been developed wherever possible using the unit cost data obtained from References 18-20. In the case of specialized hardware (eg. wind tunnel shell, test support systems, etc.), costs have been developed on the basis of the Consultant's in-house expertise and reference data developed from comparable installations in other facilities. In special cases (eg. the chassis dynamometer for Configuration No. 3), preliminary quotations were obtained from suppliers. For Categories 1-4, cost elements are broken out in some detail in order to provide a better understanding of make-up of the final totals. The special cost element for line upgrade of the Gloucester Hydro electrical feed to 27.6 kv was arrived at through consultation with the utility, and is considered to be preliminary only.

The fees developed for architectural services are calculated as a percentage of the total combined costs for site preparation and services, plus support buildings. The percentage used (15%) is considered representative of typical practice for the type of installations under consideration.

Under Category 6, engineering fees include all engineering costs associated with hardware and systems design, procurement, installation and commissioning. Programme management and constructor charges include total programme management during design, construction and commissioning of the complete facility. Programme management would involve planning and scheduling, project budgeting and cost control, procurement, construction management and supervision.

Constructor charges are comprised of overhead, warranty, financing, guarantees, insurance and margin. All of the above charges in Category 6 are calculated as a percentage of the facility hardware and electrical power distribution costs developed in Categories 3 and 4 (excluding the 27.6 kv power supply cost).

All of the costs developed in this section are in Canadian dollars, with a time reference of October, 1982. No attempt has been made to incorporate an escalation allowance on the basis of a projected acquisition schedule. Costs include subcontractors' overheads and profits, but do not include taxes or duties. Land costs are similarly excluded. The final facility cost estimates represent the cost for acquiring the Dynamic Controlled Climate Test Facility with -30°C capability at the NRC Railway Laboratory site on a turnkey design-and- supply basis. The costs for the three configurations are considered accurate to within ±20% accuracy.

6.2 Site Preparation and Services

Note: These costs do not include excavations and internal services specific to the support buildings.

ITEM	CONFIGURATION COST (x $1,000) NO. 1	NO. 2	NO. 3
1. Tree Removal	20.0	20.0	20.0
2. Parking Lot Demolition	.7	.7	.7
3. Site Grading	2.0	2.0	2.0
4. New Drainage	8.0	8.0	8.0
5. New Roads and Parking Lots	10.3	10.3	10.3
6. Relocate Leaching Field	5.0	5.0	5.0
7. New Well and Pump	3.5	3.5	3.5
8. Extend Water Lines	13.3	13.3	13.3
9. Fencing	3.5	3.5	3.5
10. Personnel Underpasses	15.0	15.0	15.0
11. Rail Spur Relocation	29.5	29.5	29.5
12. New Rail Spur and T/S Insert Storage Pad	29.3	29.3	29.3
13. Landscaping	2.6	2.6	2.6
14. Service Extension from NRC CEF	-	-	5.0
15. Relocate NRC Condensor	5.0	5.0	5.0
16. Lightning Protection	4.2	4.2	4.2
17. Road/Parking Lot/Shell External Lighting	23.0	23.0	23.0
18. Shell Region Excavations	7.8	8.4	8.4
19. Main Substation Pad and Fencing	2.8	2.8	2.8
20. Shell Internal Lighting	19.9	19.9	19.9
TOTALS -	205.4	206.0	211.0

6.3 Support Buildings

Note: The costs to follow include site work and excavations specific to the areas contained within the general support building perimeter. They also include internal services (plumbing and electrical).

ITEM	CONFIGURATION COST (x $1,000) NO. 1	NO. 2	NO. 3
1. Support Building No. 1 (Office/Control)	176.0	176.0	176.0
2. Support Building No. 2			
a) Plant Room	87.0	87.0	101.5
b) Electrical Room	28.0	28.0	28.0
Sub Total -	115.0	115.0	129.5
3. Support Building No. 3 (Make-Up Air Unit)	-	-	24.0
TOTAL -	291.0	291.0	329.5

6.4 Wind Tunnel Hardware

ITEM	CONFIGURATION COST (x $1,000) NO. 1	NO. 2	NO. 3
1. Foundations	55.2	55.7	55.7
2. Steel Shell Segments	2,167.5	2,167.5	2,167.5
3. Concrete Shell Segments	113.6	127.0	127.0
4. External Cladding and Insulation	568.8	568.8	568.8
5. Insulated Floors	32.2	38.0	38.0
6. Vehicle Access Doors	123.0	123.0	123.0
7. Test Section Inserts	287.0	408.0	408.0
8. Re-Entry Flaps	-	53.9	53.9
9. Track and Ballast	7.8	7.8	7.8
10. Fan and Drive System	1,253.0	1,253.0	1,253.0
11. Cooling/Heating System	3,960.0	3,960.0	4,748.0
12. Controls/Data Acquisition/ Safety Systems	477.9	526.0	581.2
13. Ancillary Systems			
a) Humidity System	40.0	40.0	40.0
b) Solar Simulation	-	275.0	275.0
c) Rain/Freezing Rain	-	60.0	60.0
d) Make-Up Air System	-	-	65.0
e) Exhaust Extraction	-	-	48.0
f) Tunnel Purge System	-	-	30.0
g) Dynamometer	-	-	142.3
Ancillaries Sub Total -	40.0	375.0	660.3
TOTAL -	9,086.0	9,663.7	10,792.2

6.5 Electrical Power Supply/Distribution

ITEM	CONFIGURATION COST (x $1,000) NO. 1	NO. 2	NO. 3
1. Main Substation	100.0	100.0	100.0
2. Unit Substation	55.0	55.0	65.0
3. Fan Transformer	45.0	45.0	45.0
4. 4.16 kv Switchgear, Cables Busswork	222.0	222.0	222.0
5. High-Voltage Protection and Control Cabinets	50.0	50.0	50.0
6. Motor Control Centres	135.0	135.0	165.0
7. 600 v Cable System	170.0	190.0	240.0
8. Grounding System	20.0	25.0	30.0
9. 27.6 kv Feeder Upgrade/ Extension	250.0	250.0	250.0
TOTAL -	1,047.0	1,072.0	1,167.0

6.6 Dynamic Facility Acquisition Cost Summary

ITEM	CONFIGURATION COST (x $1,000) NO. 1	NO. 2	NO. 3
1. Site Preparation and Services	205.4	206.0	211.0
2. Support Buildings	291.0	291.0	329.5
3. Wind Tunnel Hardware	9,086.0	9,663.7	10,792.2
4. Electrical Power Supply/ Distribution	1,047.0	1,072.0	1,167.0
5. Architectural Fees	74.5	74.6	81.1
6. Engineering, Programme Management, and Constructor Charges	6,890.2	7,511.7	8,151.0
TOTAL -	17,594.1	18,819.0	20,731.8

6.7 Lower Operating Temperature Options

As a supplement to the acquisition costs presented in Section 6.6 above for the -30°C operating temperature baseline, investigations have also been carried out for the case of -40°C and -50°C temperature capabilities. The technical implications of these enhanced performances have already been discussed in Section 3.8. Briefly, they involve considerable increases in cooling system performance and hardware, plus commensurate upgrading/expansion of the new Plant Room, the electrical supply (including main and unit substations), the relevant electrical distribution system elements, plus the control and safety systems. The approximate increases in dynamic facility acquisition cost over those given in Section 6.6 are as follows:

-40°C	add $2 Million
-50°C	add $6 Million

6.8 Alternatives for a Dynamic Facility Design Concept

The facility capital acquisition costs projected in the previous sub-section are obviously significant, but nevertheless unavoidable for a climatic wind tunnel class of dynamic facility. By the latter, it is meant that the intrinsic, dedicated closed-return-circuit steel shell is a large and relatively complex structure which forces high costs in both engineering, hardware, and construction. The acquisition cost associated with climatic wind tunnels is considerable for facilities sized to handle automotive testing only, and has become even higher for the facility in question where the targeted test items (large vehicles and machinery) have forced much larger return circuit dimensions.

It is worthwhile at this time to reiterate the rationale which led to the add-on climatic wind tunnel concept forming the focus of this study. In brief, the NRC add-on concept was premised on:

1. Minimized land acquistion costs
2. Reduced support staff costs (i.e. partial staffing by existing NRC employees)
3. Slightly reduced capital acquisition costs (i.e. use of the NRC CEF's test section as part of the return circuit, plus availability of existing support infrastructure and systems)
4. Capitalizing on the skills and reputation of NRC-LTL in climatic testing
5. Agreement between user survey projections for best location, and the actual location of the NRC CEF
6. Partial economies in capital acquisition and operating costs by virtue of using the NRC CEF's refrigeration system for overnight temperature-hold tasks
7. Apparent loss of much of the potential climatic testing market identified by the user survey to the new NRC CEF, with subsequent doubts raised about the validity of a new, stand-alone dynamic facility as opposed to the phased development of an existing facility

Item 7, in the opinion of the Consultants, is the dominant consideration in the add-on versus stand-alone argument, and is not necessarily answered by benefit/cost considerations alone. At the same time, Items 1 through 6 cannot be completely ignored. The decision

to pursue the add-on concept was the joint decision of TDC and the Consultants, and hinged primarily on Item 7 in the above list.

If that decision is put aside for the moment, an alternative facility design concept is available which promises significant reduction in capital acquisition costs, at the possible expense of slightly reduced airflow simulation quality. This concept is generally termed a climate chamber-type facility. It differs from the dedicated return circuit format of a climatic wind tunnel in that the first crossleg and most of the fan leg in the return circuit are comprised by normal building walls rather than a purpose- built, steel plate shell.

The climate-chamber type dynamic facility has been employed successfully by DSMA International Inc. for a number of clients in both the automotive and petroleum products industries. Its applications include elevated temperature testing, cold drivability/warmup testing, and all-weather chassis dynamometer testing for road-going vehicles. This construction concept, for the case at hand, would offer important economies in as-constructed cost and in overall space utilization.

Simply put, a climate chamber type facility would provide a dedicated steel shell structure only for that part of the return circuit where air flow management is most critical - that is, from the fan intake through to the nozzle. The remainder of the circuit would be a relatively normal building with a structural steel skeleton, Bally panel inner insulation walls, and outer walls of either concrete block or steel siding. An insulated concrete floor would still be necessary over the length of the test section and Corner 1.

It is important to note that the climate chamber concept is not considered completely amenable to an add-on approach for the NRC static facility. The already-limiting constraints of the NRC facility's test section dimensions may prove insurmountable when coupled with the restricted air flow management capabilities of the climate chamber design concept.

The Consultants believe that a climate chamber approach to the dynamic facility requirement at hand could reduce the capital acquisition cost by about $5 million. Further study will be required to

evaluate the quality of airflow simulation which could be achieved for such a design within the context of large vehicle/heavy equipment testing.

7. COST/BENEFIT EVALUATION

7.1 Basic Assumption of Cost/Benefit Analysis

Attempting to estimate the cost/benefit tradeoffs with any research-oriented investment is difficult at best. The principal difficulty is usually the uncertainty concerning the expected benefits. The dynamic controlled-climate test facility at hand falls into this category since much of the work to be done in the facility relates to the early phases in the product development cycle or to investigations of product reliability. Both of these categories of test or research effort tend to generate benefits which are only visible at a much later date and hence are extremely difficult to quantify in advance.

In addition to the usual problems of quantifying delayed benefits, this specific cost/benefit analysis is subject to some methodological difficulties with respect to estimation of operating costs. Since the proposed facility will be constructed as an extension of the new NRC Climatic Engineering Facility, care must be exercised in the definition of costs and benefits.

This analysis only deals with the costs (both capital and operating) and benefits (direct and indirect) which are "incremental" to the committed static facility. For the purposes of this analysis, these incremental costs and benefits are restricted to the following:

1. Incremental Capital - The NRC CEF test section would be incorporated into the structure of the dynamic facility. Thus the costs for the dynamic facility do not include the full capital cost of the CEF test section and support buildings, but only the costs of necessary modifications.

2. Incremental Fixed Labour Costs - Since both the CEF and the dynamic facility would share the same test section, their operation is mutually exclusive. Therefore, staff which are fully dedicated to operating and maintaining the CEF should be available to operate and maintain the dynamic facility when it is running and can be ignored when determining incremental cost. The only permanent staff costs which should be allocated to the

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dynamic facility are those of staff who are specifically hired to support the dynamic facility and who would not be effectively employed elsewhere in the operating organization.

3. Incremental Variable Labour Costs - The dynamic facility may require part-time labour from time to time. If these can be obtained on a temporary basis, only the direct cost of the time spent at the dynamic facility should be considered in the cost estimates.

4. Incremental Materials Costs - The dynamic facility would likely incur costs for hydro, testing materials, equipment spares and other items which would exceed the requirements of the CEF. To the extent, however, that maintenance items apply to common elements of the two facility components, they should be divided in proportion to the relative usage of the two facilities.

5. Incremental Testing Fees - Since all of the costs associated with the dynamic facility are incremental, the same rules should apply to any testing revenue which is generated through user fees. The only revenue which should be credited to the dynamic facility is the revenue over and above the fees charged by the static facility. In other words, any premium charged for the dynamic facility would be considered incremental revenue. An exception to this rule would occur in the event that the NRC CEF were not fully utilized. In this case, any testing fees generated by operating the dynamic facility at times which do not conflict with the CEF's operation can be credited to the dynamic facility.

6. Incremental Benefits - The concept of incremental social benefits is tightly constrained by the requirement that such benefits must represent true increases in economic resources and not simply a transfer of resources from one location to another. If the dynamic facility attracts testing activity from existing facilities, the benefits of such testing must be ignored in the analysis unless the dynamic facility is used to perform those tests in a new or improved fashion. As long as they meet these criteria, the social and economic benefits can be broadly defined to include both direct monetary benefits to users and to society as a whole.

With the above concerns in mind, the following analysis is progressively developed from relative certainty (i.e. capital cost estimates) to those areas which are less well defined (e.g. social benefits). The approach examines each of the major elements of the cost/benefit stream in turn. All of the costs and benefits listed above are assembled and compared over the life of the facility under study in the light of social discount rates. All of the above terms of reference are in conformance with Treasury Board guidelines for cost/benefit analysis (Reference 21).

7.2 Capital Cost of the Dynamic Facility

The capital cost of the dynamic facility is the most clearly defined of the costs and benefits associated with the project. The CCTF's layout, performance and functionality options have been chosen on both technical and commercial grounds.

The capital cost estimates and their rationale have been presented in Section 6. As a result, three possible designs were identified with their attendant capital costs:

1. Scenario 1 - A dynamic circuit with solid-wall test section insert suitable for the investigation of heat balance problems in rail vehicles at a cost of $17,600,000.

2. Scenario 2 - A dynamic circuit with a combined slotted-wall and solid-wall test section which would be suitable for conducting heat balance tests and would also be suitable for investigations of airflow and heat transfer around large objects such as railway locomotives and off-road vehicles at a cost of $18,825,000.

3. Scenario 3 - A dynamic circuit which does all of the above, but includes a dynamometer and permits the testing of large vehicles (but not railway vehicles) under steady-state operating conditions at a cost of $20,750,000.

7.3 Operating Costs Components

The operating costs of the dynamic facility would be affected to a large degree by the level and pattern of utilization. As the discussion in Section 5 indicated, there is considerable uncertainty

regarding the details of the test programmes which might take place in the facility. In order to evaluate the impact of operating costs, it is necessary to make assumptions which are difficult to verify. One way of handling this problem is to make a range of assumptions which can be combined to form "best case", "worst case" and "intermediate" scenarios. The operating cost estimate can then be tested for sensitivity to the range of assumptions. The following sections detail the development of the various cost elements.

7.3.1 Incremental Fixed Labour Costs

Discussion of possible staff costs are based largely on the comments provided by Mr. R. Ringer of the NRC Low Temperature Laboratory. Nonetheless, the Consultants take full responsibility for interpreting his comments and for the estimates which are presented here.

a) Operating Staff

Given the relatively sophisticated computer-based control system which is proposed for the dynamic facility, the operating personnel from the CEF should be able to manage the operation of the dynamic facility as well. The only exception to this will likely occur in the area of test setup. Dynamic testing programmes will likely be more complicated than most static tests and will require extra staff support in order to make all of the instrument hookups and to handle the extra chores involved with the removable test section liner. It is therefore assumed that the dynamic facility will require 1 extra man-year's worth of trained operating staff for these activities, at a direct labour cost of approximately $25,000. per year.

b) Maintenance Staff

Apart from the refrigeration system, the dynamic facility is expected to require 1 man-year for maintenance of the plant room and the support buildings and 0.5 man-years for grounds maintenance of the expanded test site. At an average direct labour cost of $20,000. per year, this requirement would add $30,000. per year.

c) Refrigeration Plant Staff

Maintenance of the refrigeration plant for the dynamic facility represents the single most sensitive operating cost in this entire analysis. This is due to the size of the refrigeration plant which is required to provide for dynamic cooling. Unlike the much smaller refrigeration plant for the CEF, the one for the dynamic facility would not be suitable for unattended operation according to current provincial safety guidelines. A qualified stationary engineer must be present whenever the refrigeration system is operating. In addition, Mr. Ringer has indicated that he expects that two people would be a realistic shift size. Moreover, he felt certain that people qualified to supervise this class of equipment would not be available on a temporary basis from other areas of NRC and would have to be hired specifically for the dynamic facility.

Due to the relatively long cooldown time for the dynamic facility,it would be preferable to have the option of two-shift and even three- shift operation from time to time. This would require, however, that a permanent staff of 6 to 9 qualified individuals be hired for the dynamic facility. At an average annual salary of $28,000. this would result in an annual direct labour cost of between $170,000. and $250,000. for refrigeration system maintenance alone.

Fortunately, there appear to be ways in which this cost can be minimized, at least until the dynamic facility becomes heavily utilized. One approach would involve using the dynamic circuit's refrigeration system to cool the facility during a standard eight hour shift and then using the CEF's automatic refrigeration system to maintain the temperature overnight. Even if the CEF's refrigeration system cannot quite maintain the lowest temperature, it should be possible to get in almost a full shift worth of testing the next day and to repeat the process each night. This method would allow the dynamic facility to operate with a single shift staff of two persons for a fixed annual direct labour cost of $56,000.

It is also possible that provincial guidelines on refrigeration plant staffing requirements will change between 1982 and the time the facility could be brought into operation. It is common

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in Europe, for example, that refrigeration plants of this scale are unmanned and are run entirely by automatic control systems. Should this practice be accepted here during the life of this facility, the proposed control system should permit unmanned operation with minimal modifications.

d) Research Staff

Mr. Ringer stated strongly that, before NRC participate in a proposal to Treasury Board for funding, they would insist that the proposal include allowance for the additional staff required to run the dynamic facility. He felt that the increased scale and complexity of the tests carried out in the dynamic facility would require at least two to four additional research and technical officers at average salaries (including benefits) of $40,000. and $32,000. respectively. Some of this cost could be reduced if facility utilization is not heavy. Until the dynamic facility became well established, there would likely be a great deal of NRC involvement in designing and evaluating prospective testing programmes for it. It seems likely, therefore, that research staff could be productively employed at tasks other than those directly related to dynamic facility operation and that the full salaries of these staff should not be applied to the facility until utilization builds up.

As with the refrigeration staff, there is a range of possible fixed labour costs which extend from two researchers working part time (approximately $50,000. per year) to four researcher working full time (approximately $145,000. per year).

7.3.2 Indirect Labour Costs

It is difficult to estimate accurate labour overhead and administration costs for a new facility, especially one that would be built as an adjunct to an existing facility. For the purposes of this analysis, however, it has been assumed that indirect charges on labour will amount to 80% of the direct labour costs. While this value is somewhat arbitrary, it is in line with the relatively lean management one would expect from what is expected to be a part time test facility.

7.3.3 Incremental Material Costs

a) Hydro

At full power, the dynamic facility is expected to draw between 6200 and 8700 kva, depending upon the configuration. Figure 18 shows how the monthly electricty cost varies with both peak load and accumulated monthly kW-h consumption. The costs for electricity are composed of these two distinct elements.

A major component of the hydro costs is the peak load charge. The local utility will charge a fixed fee each month which is directly related to the maximum instantaneous apparent power (kva) which is drawn during the month. At 1982 prices, these charges are $7.70/kva. This translates into a fixed monthly charge of between $48,000. and $65,000. depending on the facility configuration.

Over the course of a year, the dynamic facility will probably be inactive for eight or nine months. It may be possible to negotiate a reduction in the peak load charges for these months, although the extent of such a reduction could only be determined through negotiations with the local utility. The Consultants believe that a 50% reduction is a reasonable expectation, and this figure will be used for all subsequent cost estimates. The peak load charges drop to between $24,000. and $33,000. per month based on the 50% reduction during inactive months.

In addition to the peak load charges, the facility will incur energy utilization charges which in 1982 amounted to $0.0145 per kW-h. Thus if the facility were operated at full power for twenty shifts of eight hours each in a month, the cost would be approximately $12,500. to $17,500. depending on the testing schedule and the facility configuration.

b) Materials and Spares

Purchase of supplies and testing equipment will be heavily dependent upon the test programmes undertaken. It is very difficult, therefore, to predict what such expenditures will be. An assumption has been made, however, that any costs exceeding $20,000. per month of operation would represent extraordinary expenditures and would be paid for by the organization commissioning the test which required them.

Facility maintenance and spares expenditures should be relatively modest. Most of the components in the dynamic facility are expected to be low maintenance items. An annual expenditure estimate of $40,000. should provide for the costs of paint, cleaning materials, computer maintenance contracts and the like.

7.4 Net Investment in the Dynamic Facility

The assumptions described in the preceding sections are summarized in the series of facility cost estimates which are presented in Tables 3 through 5. The first three tables show the expenditure flow which is expected for the facility during the construction period and during the first 10 years of operation. For Tables 3 through 5, the most extensive configuration is depicted and three operating cost estimates are applied. The cost estimates in Table 5 are consistent with the most pessimistic view of the cost components described in Section 7.3. Table 4 is consistent with more moderate assumptions, while Table 3 is consistent with a very optimistic scenario in which it is assumed that the operating agency is very resourceful in optimizing operation of the facility.

A key assumption in the three tables is the expected utilization rate, which is a guess based on the following observations:

1. During the market survey, from all the companies canvassed, firm statements of intent to test amounted to only about three months per year. Furthermore, it is unlikely that all of this testing volume would emerge in the first years of operation.

2. During discussions with Mr. Ringer, his best estimate of likely interest in testing was also about three months worth of dynamic testing each year.

Given these forecasts as a basis, a reasonable scenario for dynamic facility utilization is to assume that usage will start off at about two months (totalling 30 days of testing) and will increase each year. The growth is dependent on the availability of all of the features which are included in Configuration 3. This is the pattern depicted in Tables 3 through 5. Based on these projections, the annual operating cost will vary between $900,000. and $1,400,000. in the first few years of operation and between $1,050,000. and $1,550,000. in the later years (all in 1982 dollars).

7.5 Incremental Testing Fees

Even more difficult than predicting operating costs is the estimation of appropriate user fees. It does not seem likely that the operators of the dynamic facility would ever be able to charge high enough fees that operating costs, let alone capital costs, would be directly recovered. Reference to Table 3 indicates that, even with the most optimistic scenario and after allowing demand to develop to 90 days per year, the annual operating cost of $1,050,000. (1982 dollars) would require a premium to be charged of over $11,700. per day. It should be remembered that this figure represents an amount over and above what would normally be charged for the use of the NRC CEF.

The highest analogous testing fee that the market survey was able to find was on the order of $3,500. per day to test a rail car. This was considered to be very high by the user and was a motivating factor in generating interest in the CCTF. The premium alone (i.e. not including the base fee for the CEF) for the dynamic facility would be more than double the $3,500. and would certainly discourage all but the most desperate potential users.

Based on the comments which were forthcoming in the market survey and based on the views of Mr. Ringer, it seems that the most that could be levied for the use of the dynamic facility would be $1,000. to $2,000. per day on top of the NRC CEF fee.

7.6 Calculation of Present Value of Investment and Operating Cost

Application of a $2,000. per day testing fee premium would reduce the required operating subsidy slightly, but would still result in an initial annual operating deficit of between $840,000. and $1,320,000. depending on the operating scenario. There is some hope that the operating deficit would tend to be at the lower end of the range. The operators and users of the dynamic facility should benefit from a significant learning curve and should be able to develop streamlined operating procedures.

When the capital costs, operating costs and predicted testing revenue are combined into one summary, a present value cost can be

calculated for the facility as a whole. Table 6 shows the resulting values for the three different dynamic facility configurations and for a range of operating cost assumptions. The discount rate which has been assumed in Table 6 is 10%.

The notable points about the present values shown in Table 6 relate to the estimates of dynamic facility usage as a function of facility capability. Tables 3 through 5 were calculated for Configuration 3. This configuration has the most extensive testing capabilities of the three and should be able to attract the highest level of test activity. If Configuration 2 were built, the testing which depends upon use of the dynamometer would not be forthcoming. This would probably reduce the maximum testing activity to nor more than 50 days per year. If Configuration 1 were built, the rail passenger car manufacturers and some human factors studies would be the only likely candidates to use the facility. Based on the level of commitment expressed during the market survey, it is doubtful if their activities would exceed 30 to 40 testing days per year.

If the above assumptions are made concerning the usage of the dynamic facility, the results shown Table 6 are easily explained. As was seen in Tables 3 through 5, most of the operating costs associated with the facility are fixed, with the exception of hydro usage costs which are directly related to facility usage. As a result, the operating costs do not change drastically from configuration to configuration. The differences seen in Table 6 are largely due to the differences in capital cost.

In addition to the direct testing activity which the proposed facility would support, however, the facility would provide a site for substantial research and development activity with respect to extreme temperatures and moving air. The connection with the NRC Low Temperature Laboratory would further enhance its attractiveness in this regard. It is reasonable to assume that the presence of this facility would generate a level of research work at least equal to activity already projected for the industrial testing.

A cost scenario has been generated which reflects this research-augmented activity and is depicted in Table 7. According to this scenario, the operating costs would remain relatively fixed with respect to the previous three scenarios, but the increased test activity due to research-oriented work would result in more than

double the total testing utilization. Since the operating costs of the facility are expected to be relatively fixed on an annual basis, the result is a substantial reduction in the average daily testing costs.

7.7 Social Benefits from the Dynamic Facility

There are two classes of benefits which can be considered to be relevant to the development of this type of facility. The first major class of benefit is the positive impact that the test results gained from such a facility would have on Canadian industry. The second class of benefit are the social beneifts that research in climatic phenomena might bring to the Canadian economy and life-style.

The second class of benefits are impossible to estimate and can only be judged by the level of interest which was generated among government agencies and in academic circles. The interest was generally limited, with the exception of the research aims of NRC and the defence implications represented by LETE. Others who were contacted expressed interest, but without a clear idea of what form their participation would take.

The benefits which would be derived from the use of the dynamic facility by industry are either very easy to quantify or almost impossible. One approach to treating the benefits is to assume that industrial organizations can estimate the value of a service and that the testing revenue projections described in the preceding section represents the value of the test facility to the participating companies. If this is the case, it is apparent that the dynamic facility could never justify itself on a cost/benefit basis.

On the other hand, very few research facilities constructed by government are expected to be self-supporting out of testing revenue. Those that are often rely on higher testing fees for non-Canadian users. The treatment of the U.S. market has been beyond the scope of this study, but it is resonable to assume that this much larger market would generate some significant amount of demand for what would be a unique facility in North America. Nonetheless, reference to Tables 3 through 5 suggests that capital recovery is unlikely, whatever the level of utilization.

The Consultants considered attempting to establish the direct and social benefits which would accrue to Canadian industry from the construction of the proposed dynamic facility. Apart from the estimates of client testing revenues, there are no apparent means of assessing the scope of such benefits. It is the opinion of the Consultants that attempts to put a dollar figure on the value of this sort of test facility would be a fruitless and expensive exercise. This conclusion is drawn from the conversations and interviews which took place during the User Survey phase of the study. Briefly, the reasons for drawing this conclusion are as follows:

1. The testing capabilities which are the basis for the design of the dynamic facility and which are the driving force in its cost (i.e. airflow simulation, low temperature simulation and large physical scale) make the proposed facility unique in North America and, for many applications, unique in the world.

2. The research and testing programmes which this facility could uniquely support have little or no precedent in the North American industrial testing community. The companies which were approached by the Consultants had, for the most part, never been faced with the possibility of conducting large-scale, fixed-facility climatic simulations. They were not prepared to speculate in any significant way on the value such a facility might have for their firms.

3. The ideas for testing which were generated by the firms surveyed were so varied and firm-specific that the Consultants could not meaningfully generalize their implied benefits on an industry-wide or economy-wide basis. The cost of estimating the social benefit from these widely varying, firm-specific test requirements would be a costly undertaking, with dubious prospects for success.

Accordingly, the Consultants have concentrated on establishing the performance and design concept for a dynamic facility which would be as versatile as possible, and yet would meet the needs of the specific constituencies identified in the railway equipment industry.

Accurate definition of the social benefits of the proposed facility will only be possible when potential Canadian industrial clients have been made aware of a specific facility design concept. This study and this report should go a long way towards increasing this awareness. Subsequent discussions with Canadian industry should prove much more fruitful with a specific design concept as a basis for discussion. It was a noticeable phenomenon that, towards the end of the study, followup discussions with industrial organizations elicited much more precise and considered responses than the initial approaches had achieved.

While it is not feasible to quantitatively assess the benefits which would be generated by such a facility, there are a number of qualitative benefits which can be identified. Most of these benefits derive from the unique capabilities of the proposed design and the fact that the facility would offer the opportunity to investigate the effects of temperature extremes combined with moving air on much larger scale objects than is now possible with other fixed facilities. Section 2.5 listed a number of testing and research activities which might take place in a dynamic facility of the type proposed.

In summary, it is apparent to the Consultants that this facility cannot be justified solely on the basis of currently committed demand for industrial testing. Rather, it represents a research investment which must be made in advance of probable usage. If such a facility were in place, it would prompt Canadian (and possibly American) industry to consider it as a research and testing tool and to actively look for ways of using it.

Quite apart from the question of whether or not the facility should be built, reference to Table 6 shows that the present values for the cost of the dynamic facility fall within a relatively narrow range. For any given operating assumption, Configuration 3 is no more than 19% more expensive than Configuration 1 and never more than 10% more expensive than Configuration 2. Since Configuration 3 offers a large increase in testing capability, it would be of potential value to a much broader range of Canadian industrial organizations. It is the subjective opinion of the Consultants that the economic benefits from Configuration 3 will be much greater than for the other two arrangements. In other words, if the dynamic facility is built, it should be constructed according to Configuration 3.

7.8 Summary

After examining the possible market for utilization of the dynamic test facility, it seems to the Consultants that at least one more step may be required in the evaluation process. This study has assessed the technical requirements of potential users and has generated three specific designs for a range of functional capabilities. Nonetheless, the process has not succeeded in getting firm commitments from Canadian industry to use the facility.

One possible approach is to take the detailed technical discussion in this report (perhaps under separate cover) and use it as the basis for detailed discussions and negotiations between the Transportation Development Centre, the National Research Council and the Canadian companies identified in the market survey. This would provide industrial organizations with a detailed and visual description of the dynamic facility concept. If the organizations were given a reasonable period in which to digest and consider the facility capabilities, they might be able to give the definitive answers that are needed in order to solidify the present subjective assessment of facility benefits.

The alternatives to further study are to construct the facility on the basis of a belief that testing activity will emerge, or to suspend the project entirely until such time as more definite interest is expressed by industry. The first alternative demands a front-end investment based on faith, while the second may result in the facility never being built because Canadian industry does not understand the capabilities which could be made available to them.

8. SUMMARY AND RECOMMENDATIONS

8.1 Summary

A three-phase feasibility study has been completed with regards to the design, acquisiton, and potential utilization of a new Dynamic Controlled-Climate Test Facility (climatic wind tunnel) in Canada. Primary elements of the study were:

1) User Survey
2) Conceptual Design
3) Benefit/Cost Analysis

A. User Survey

The first phase of the study solicited interest in controlled climatic testing via questionnaire format from 140 Canadian corporations, ten Canadian federal government agencies, and 22 Canadian universities and colleges. Contacts with prospective test clients in the United States were excluded from the terms of reference for the study. Detailed follow-up interviews were carried out with the 30 most promising industrial contacts and eight of the government contacts. Highlights of the survey results were as follows:

i) Industry response to the prescreening questionnaire exceeded 66%.

ii) Almost 90% of the industrial respondents to the question naire indicated that their products were subject to design constraints and/or operational problems as a consequence of exposure to adverse or varied climatic conditions.

iii) There are no Canadian test facilities (industrial or government-owned) in existence with the capability for testing large vehicles/equipment under dynamic, controlled-climate conditions.

iv) 90% of the controlled-climate testing need identified by the survey can be adequately met by a static facility (i.e. static hot/cold room), assuming a comparable range of temperature capability.

v) There is minimal current interest amongst Canadian university/college researchers in dynamic controlled-climate testing of large vehicles/equipment.

vi) Relatively strong interest in dynamic controlled-climate testing of large test items exists amongst the following Canadian federal government agencies:

- Department of National Defence
  a) Defence and Civil Institute of Environmental Medicine
  b) Land Engineering Test Establishment (DND)

- National Research Council of Canada
  a) Low Temperature Laboratory
  b) Railway Laboratory

- Transport Canada
  a) Transportation Development Centre

vii) Strong interest in dynamic controlled-climate testing of large equipment was expressed by a limited but important group of corporate contacts, notably within the inter-city and urban rail transportation sectors (both manufacturing and operations).

viii) More than 90% of the most promising candidates for dynamic controlled-climate testing of large equipment are located within southern Ontario and Quebec.

B. Facility Conceptual Design

Design of a facility suitable for meeting the requirements for dynamic testing identified by the User Survey is quite feasible. Conceptual designs for such a facility have been carried out, concentrating on three levels of increasing test capability. For reasons of cost and projected utilization, all of the conceptual designs are configured as phased developments of the National Research Council's new Static Climatic Engineering Facility, located at the Railway Laboratory near Uplands Airport, Ottawa. Although this 'add-on' strategy results in relatively minor savings with regards to dynamic facility hardware

costs, important economies are realized in operating costs, land acquisition and site preparation. Noteworthy aspects of the proposed designs are as follows:

i) The dynamic facility will consist of the addition of a large, ground-level, closed-loop air return circuit and two new support buildings.

ii) Integration within the existing NRC site and buildings can be accomplished without significant detriment to any on-going activities or existing structures.

iii) Capital acquisition and operating costs make it inadvisable to provide for basic airspeeds in excess of 100 km/h and minimum test temperatures below -30°C. Windwipe tests for long rail vehicles will be possible for airspeeds in excess of 200 km/h.

iv) The recommended facility will offer the following special test capabilities:

- humidity control
- solar simulation
- rain/freezing rain simulation
- chassis dynamometer testing of wheeled (non-rail) vehicles for drive configurations up to 6x6 and road power outputs up to 375 kW

v) Snow simulation and chassis dynamometer testing of tracked vehicles are feasible, but will require separate and costly development programmes.

vi) Supply of electrical power for the facility will require extensive planning and negotiations with the local utility.

vii) Temperature pulldown performance of the proposed facility will be a critical element with regards to staffing requirements and facility productivity.

C. Benefit/Cost Analysis

Capital acquisition costs for the three facility configurations will range from $17.6 million to $20.7 million (estimated to ±20% accuracy in October 1982 Canadian dollars), depending on level of testing capability. In view of the relatively small incremental cost for acquisition of the highest-capability configuration, it is recommended that the two lower-level configurations be eliminated.

Results of the User Survey Study suggest an initial maximum utilization for the dynamic facility of 30 testing days annually, rising progressively to 90 days after 10 years. An intermediate cashflow analysis based on these figures predicts an operating subsidy requirement of $35,000. per testing day for the facility.

The Consultants believe that utilization predictions for the facility are understated. In almost all of the follow-up discussions held with prospective test clients, representatives of the company/agency were essentially ignorant of dynamic, controlled-climate, fixed-facility testing in terms of capabilities, precedents, costs, availability and benefits. The Consultants believe that if the proposed facility is implemented and successfully used by one or two high-profile corporate clients, 'copy-cat' testing on the part of competitors or comparable-application manufacturers may generate sigificant increases in utilization. There is, of course, a 'chicken and egg' element to this argument, and the degree of risk is obvious given the projected cost estimates for acquiring the facility.

The Consultants also believe that the potential testing load stemming from pure research activities may easily double that projected for design/development applications in the dynamic facility. It is unlikely, however, that research programmes requiring such a class of facility will be defined by the sponsoring agencies/corporations until after the facility is made available.

8.2 Recommendations

The Consultants have determined low to moderate Canadian interest in controlled-climate testing of large equipment under dynamic conditions. A limited number of high-profile testing clients have been identified as being very interested. Financial risk in terms of acquisition and operating costs for a suitable facility are considered quite high, given current projections of utilization. There is no indication, however, that a dynamic controlled-climate test facility of the class under consideration would be built independently by any Canadian industrial concern, particularly within the next five years.

Realization of a climatic wind tunnel class of facility is considered technically feasible, but is recommended only as a phased development of the existing Climatic Engineering Facility at the National Research Council's Railway Laboratory.

Important economies in capital acquisition cost for a dynamic facility could be realized in a stand-alone, climate chamber class of facility, at the expense of some accuracy in the quality of simulation. Further study of this alternative configuration is recommended.

It is the overall recommendation of this study that Transport Canada initiate a programme of discussions with a selected group of prospective testing clients within the Canadian (and perhaps United States) industrial community. These discussions should focus on the conceptual design segment of this report in an attempt to familiarize the companies with potential applications and benefits to be derived from a defined facility configuration and capability. The potential for entering the preliminary engineering and detail design phases for the dynamic facility should be judged on the basis of utilization proposals and guarantees derived from these discussions.

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FIGURES

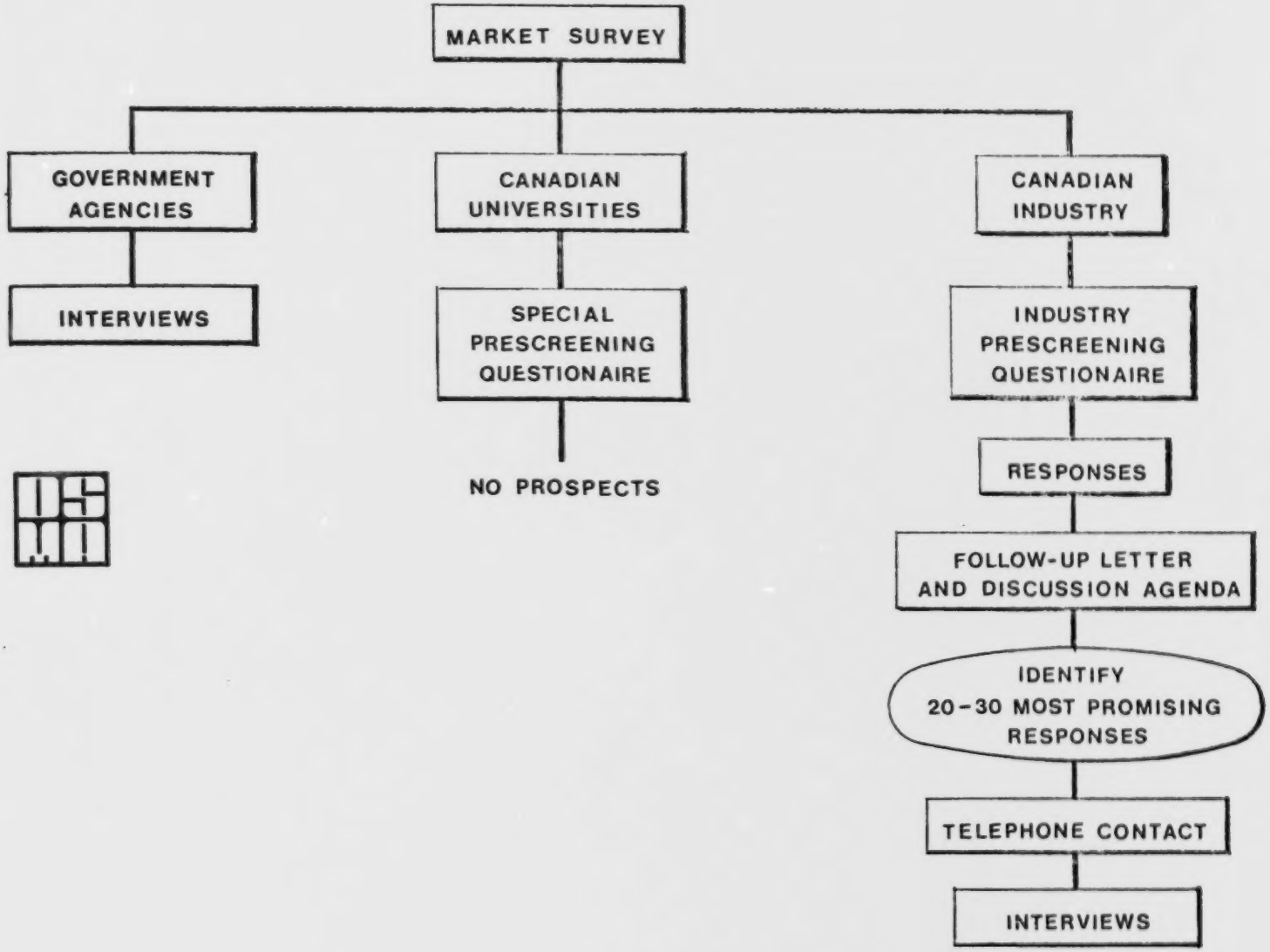


Figure 1. USER SURVEY - METHODOLOGY

TDC CONTROLLED-CLIMATE TEST FACILITY STUDY

USER SURVEY – PRESCREENING QUESTIONNAIRE RESULTS

User Category : Road Transportation Vehicles

Level of Response : 16 of 32

23 % of Survey Population
17 % of All Respondents

Figure 2

TDC CONTROLLED-CLIMATE TEST FACILITY STUDY

USER SURVEY - PRESCREENING QUESTIONNAIRE RESULTS

User Category : Off-Highway Vehicles

Level of Response : 29 of 38

27 % of Survey Population
31 % of All Respondents

PERCENT OF OF RESPONDENTS ANSWERING 'YES'

100% 80% 60% 40% 20% 0%

All Categories 59%

This Category 93%

78% of Positive Respondents

QUESTIONS ASKED		
Climatic Impact On Designs, Operations	Problem Areas	Mechanical Failures
		Reduced Performance
		Operator Efficiency
		Design Setting Adjustments
		Other
	Climatic R & D	Regularly
		Occasionally
		Never
	Facilities Used	Company
		Affiliate
		Industry-Shared
		Field Test
		Government
		Private Contract
		No Tests

Figure 3

TDC CONTROLLED-CLIMATE TEST FACILITY STUDY

USER SURVEY - PRESCREENING QUESTIONNAIRE RESULTS

User Category : Inter-City and Urban Rail

Level of Response : 12 of 12

9 % of Survey Population
13 % of All Respondents

PERCENT OF OF RESPONDENTS ANSWERING 'YES'

100% 80% 60% 40% 20% 0%

All Categories 59%

This Category 92%

64% of Positive Respondents

QUESTIONS ASKED		
Climatic Impact On Designs, Operations		
	Problem Areas	Mechanical Failures
		Reduced Performance
		Operator Efficiency
		Design Setting Adjustments
		Other
	Climatic R & D	Regularly
		Occasionally
		Never
	Facilities Used	Company
		Affiliate
		Industry-Shared
		Field Test
		Government
		Private Contract
		No Tests

55%
0
18%
64%
64%
9%
0
64%
36%
18%
91%
64%
82%
64%

Figure 4

TDC CONTROLLED-CLIMATE TEST FACILITY STUDY

USER SURVEY – PRESCREENING QUESTIONNAIRE RESULTS

User Category : Aerospace and Support Equipment

Level of Response : 10 of 12

9 % of Survey Population
11% of All Respondents

Figure 5

TDC CONTROLLED-CLIMATE TEST FACILITY STUDY

USER SURVEY - PRESCREENING QUESTIONNAIRE RESULTS

User Category : Petroleum, Mining and Materials Handling

Level of Response : 12 of 23

16 % of Survey Population
13 % of All Respondents

Figure 6

TDC CONTROLLED-CLIMATE TEST FACILITY STUDY

USER SURVEY – PRESCREENING QUESTIONNAIRE RESULTS

User Category : Marine Equipment

Level of Response : 4 of 8

6 % of Survey Population
4 % of All Respondents

PERCENT OF OF RESPONDENTS ANSWERING 'YES'

100%
80%
60%
40%
20%
0%

All categories 59%

This Category 50%

50% of Positive Respondents

QUESTIONS ASKED	Problem Areas								Climatic R & D			Facilities Used						
	Climatic Impact On Designs, Operations	Mechanical Failures	Reduced Performance	Operator Efficiency	Design Setting Adjustments	Other	Regularly	Occasionally	Never	Company	Affiliate	Industry–Shared	Field Test	Government	Private Contract	No Tests
		50%	50%	25%	75%	0	0	75%	25%	75%	0	0	50%	0	25%	25%

Figure 7

TDC CONTROLLED-CLIMATE TEST FACILITY STUDY

USER SURVEY - PRESCREENING QUESTIONNAIRE RESULTS

User Category : Electrical Equipment and Services

Level of Response : 9 of 11

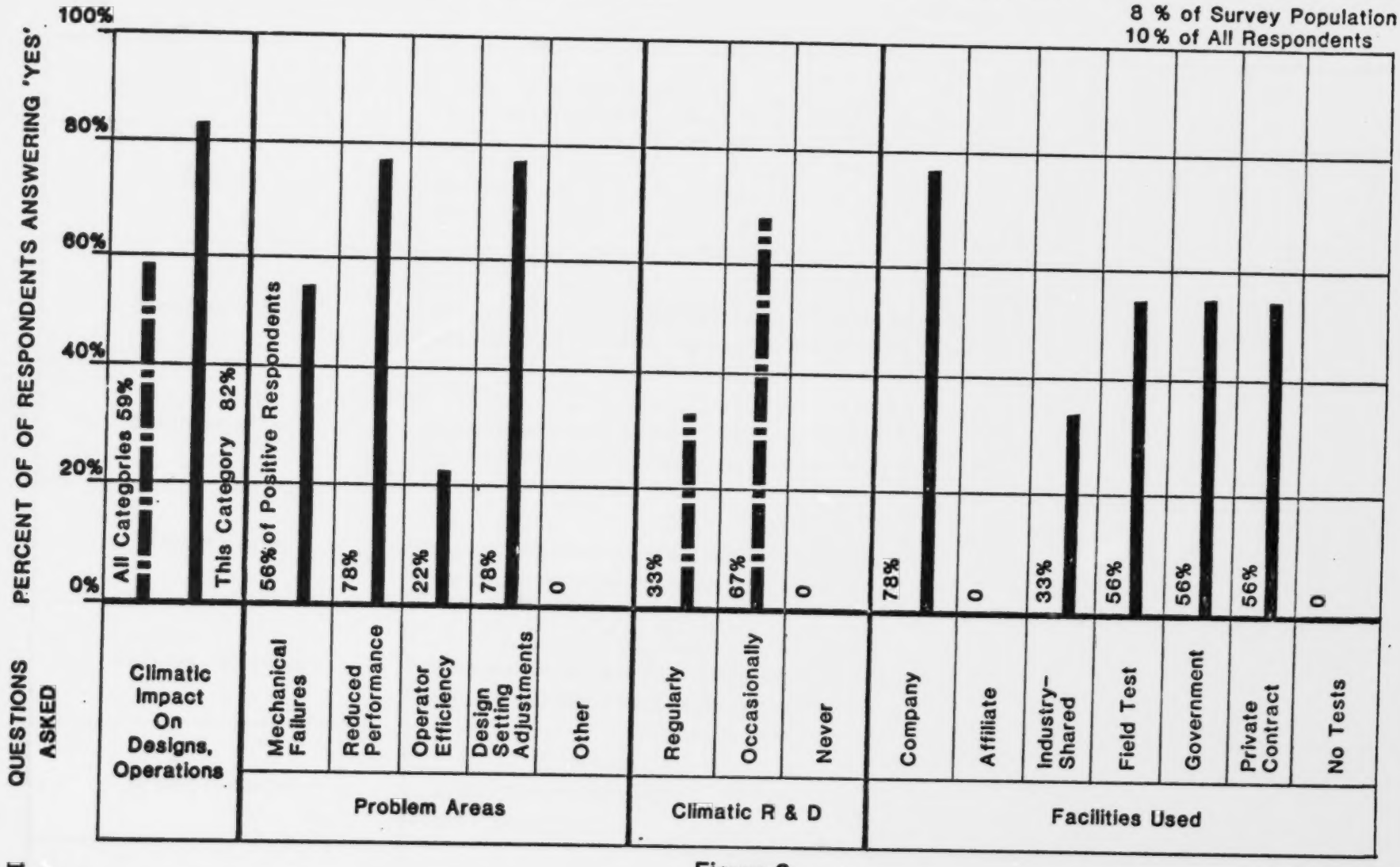


Figure 8

TDC CONTROLLED-CLIMATE TEST FACILITY STUDY
USER SURVEY - PRESCREENING QUESTIONAIRE RESULTS

LEVEL OF RESPONSE BY GEOGRAPHIC REGION

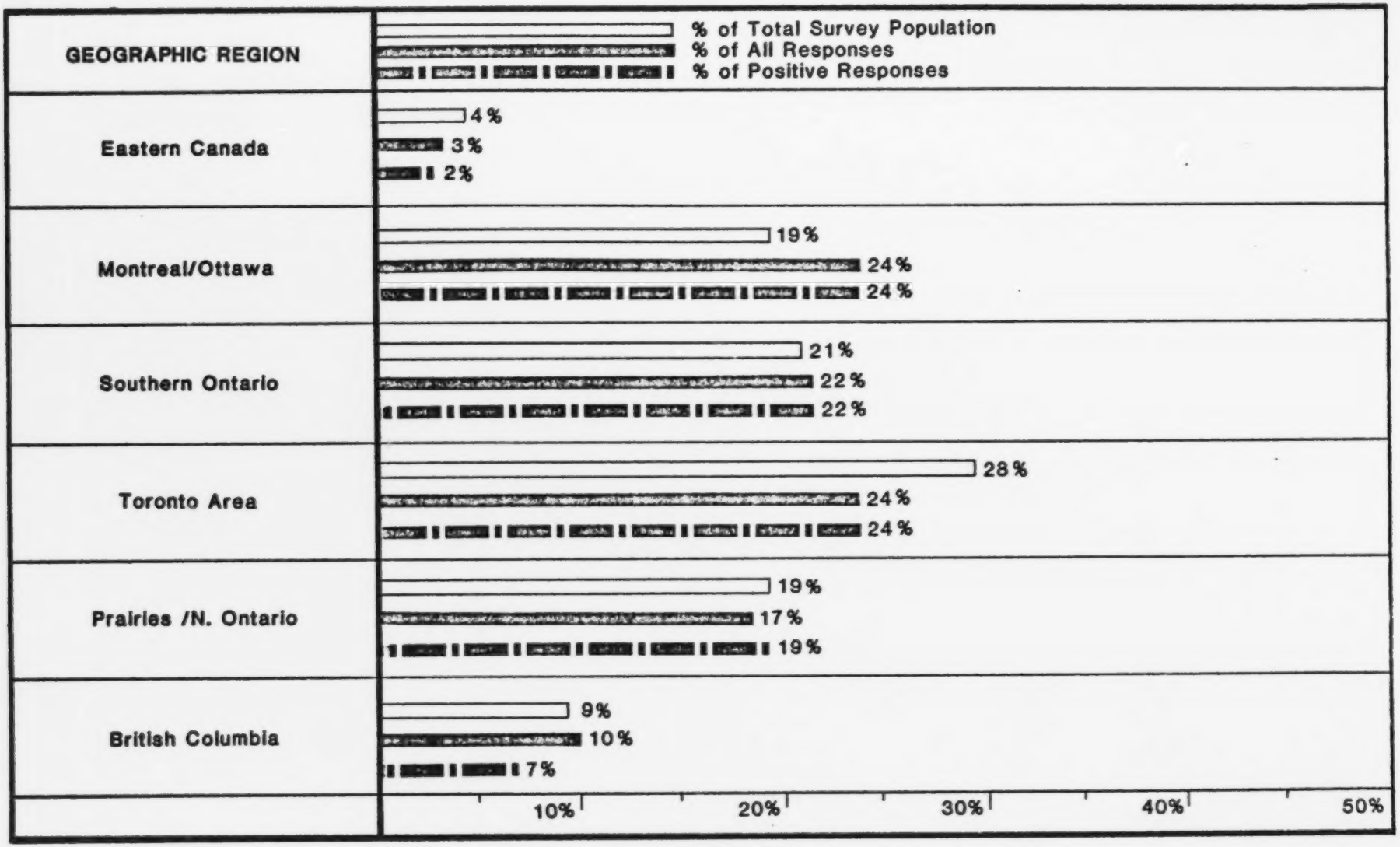


Figure 9

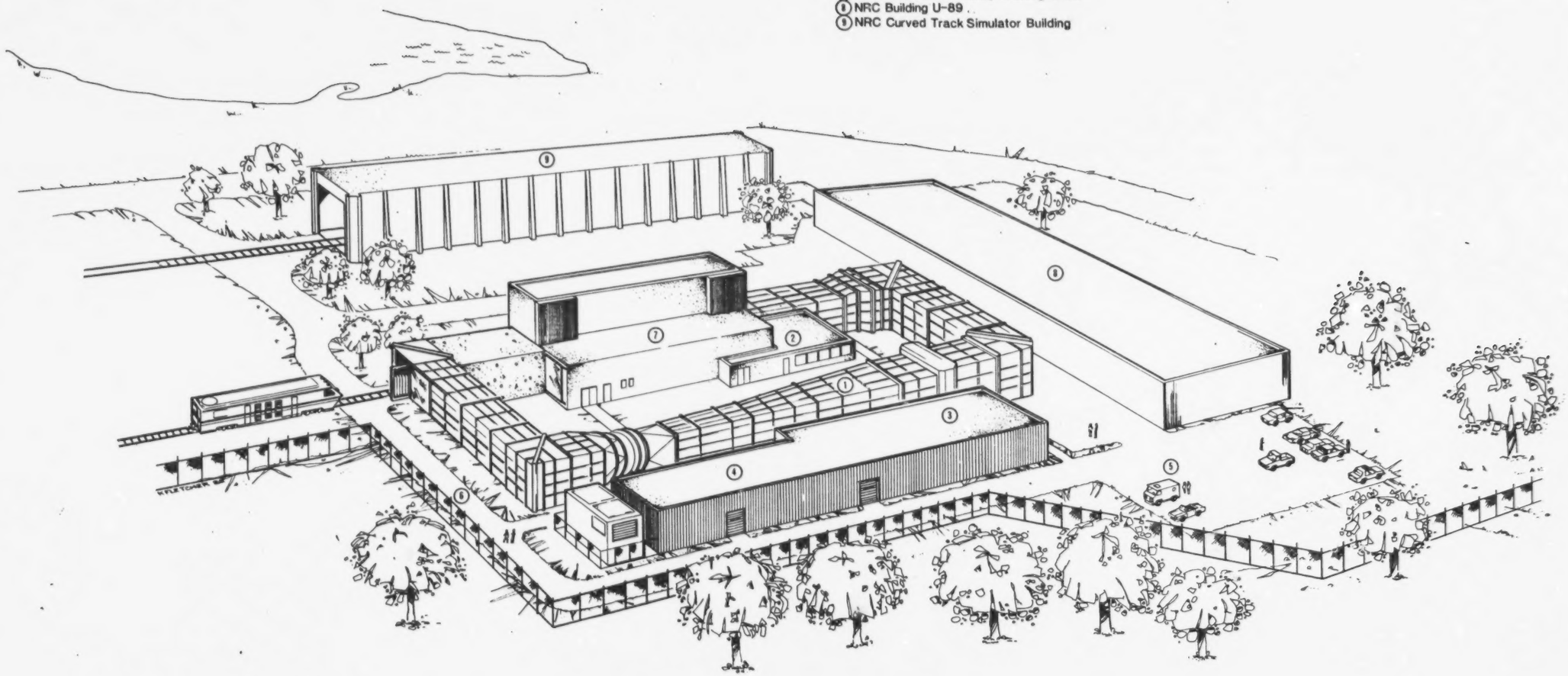

1 Dynamic Test Facility Return Loop
2 New Support Building
3 New Plant Room
4 New Electrical Room
5 New Parking Lot
6 New Access Road
7 NRC Static Test Facility Building U-88
8 NRC Building U-89
9 NRC Curved Track Simulator Building

Figure 10. Transport Canada Dynamic Controlled-Climate Test Facility:
Site Drawing for the Phased Development of
the NRC Climatic Engineering Facility

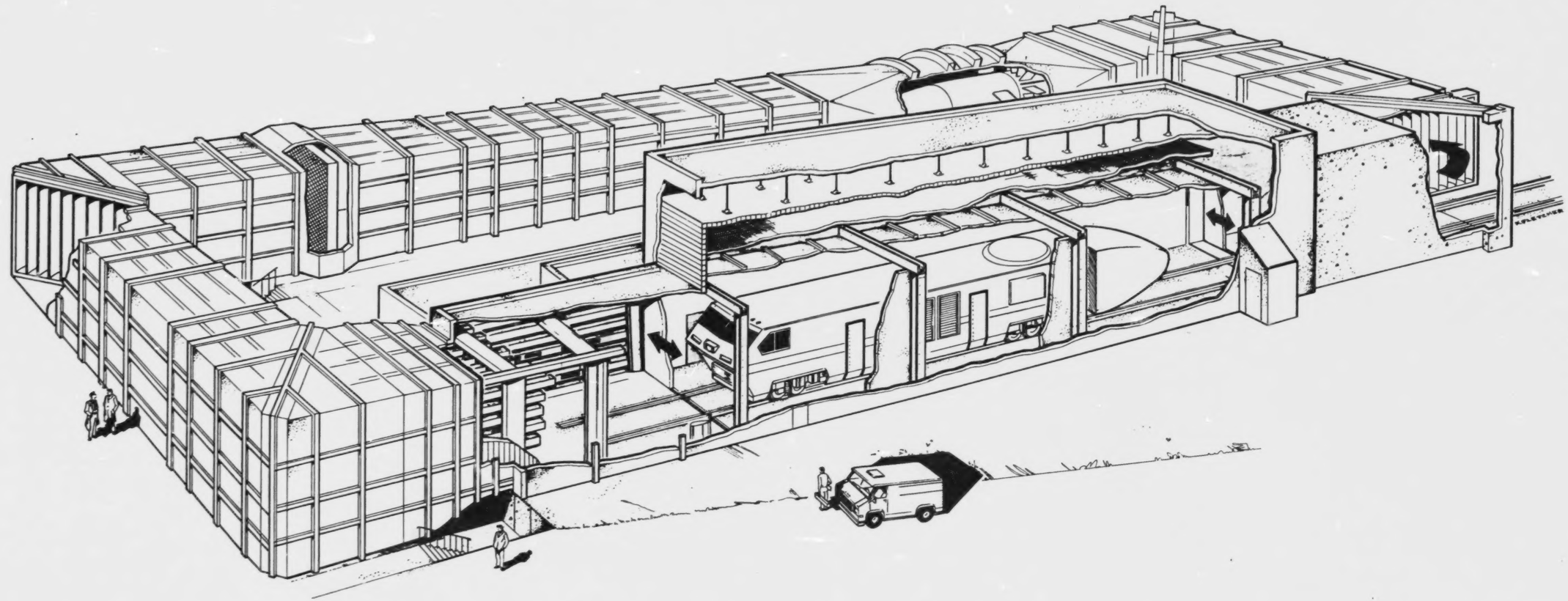


Figure 11. Transport Canada Dynamic Controlled - Climate Test Facility:
Tunnel Shell Configuration for Phased Development of
the NRC Climatic Engineering Facility

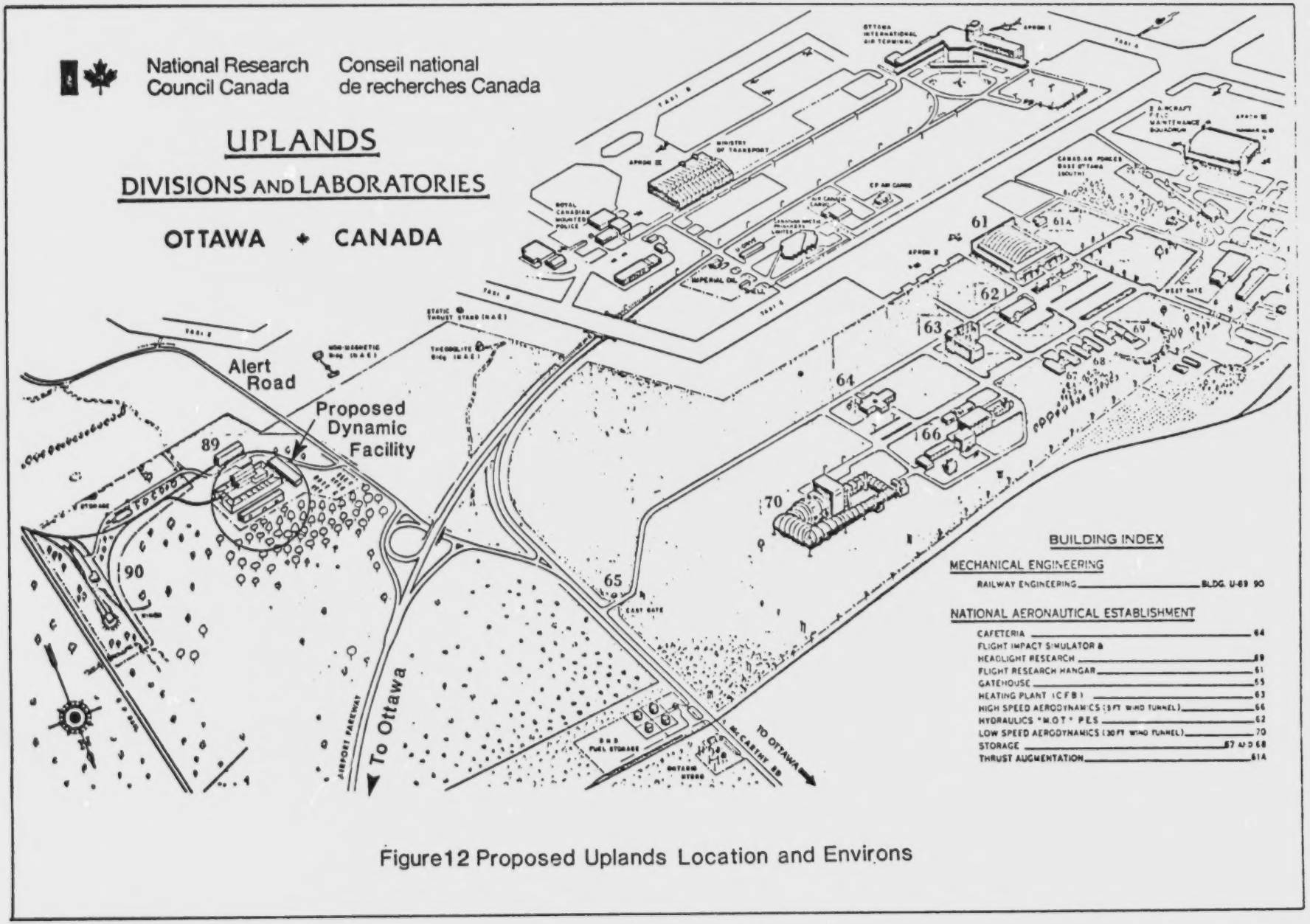


Figure12 Proposed Uplands Location and Environs

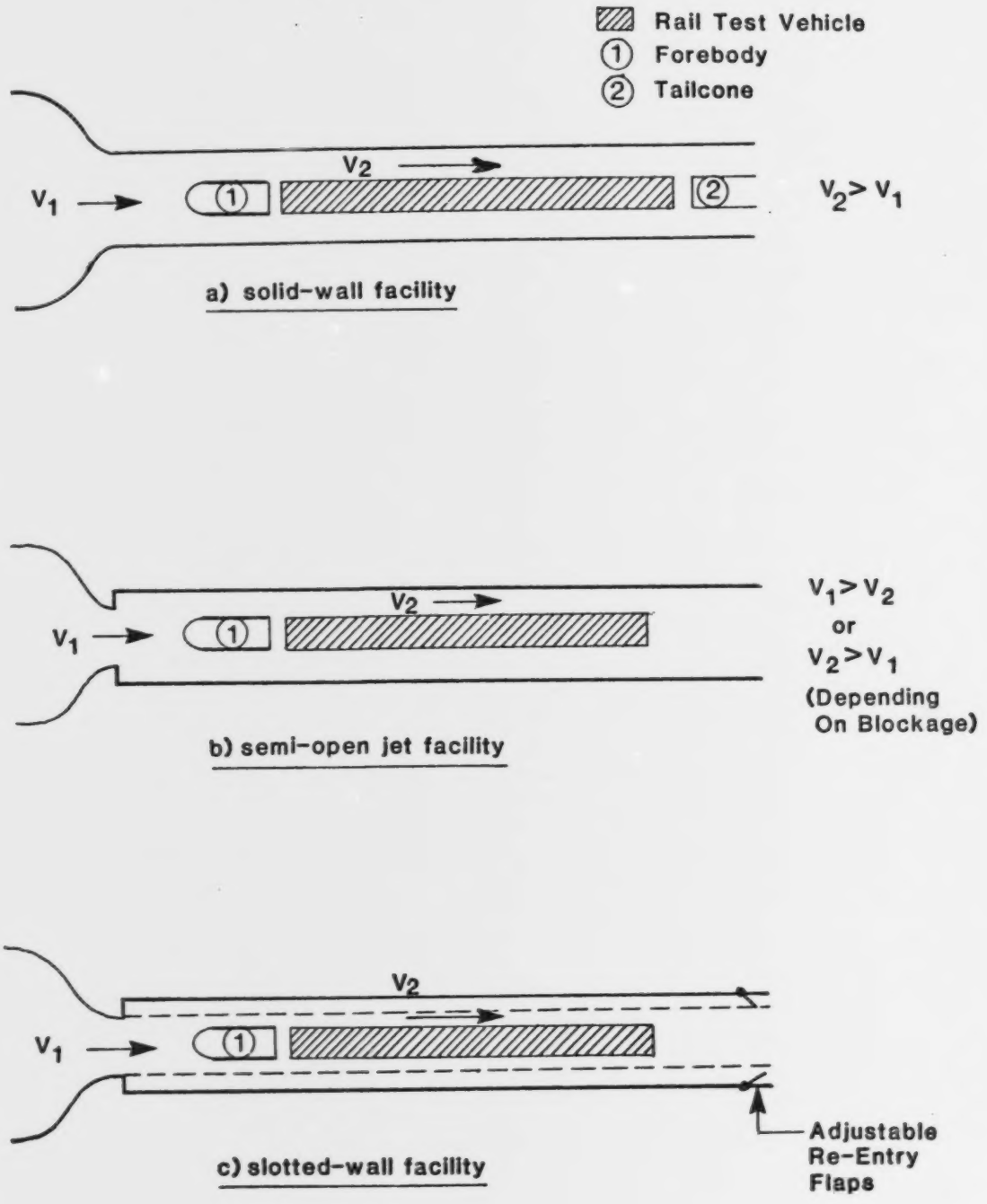


Figure 13 Test Section Configuration Options

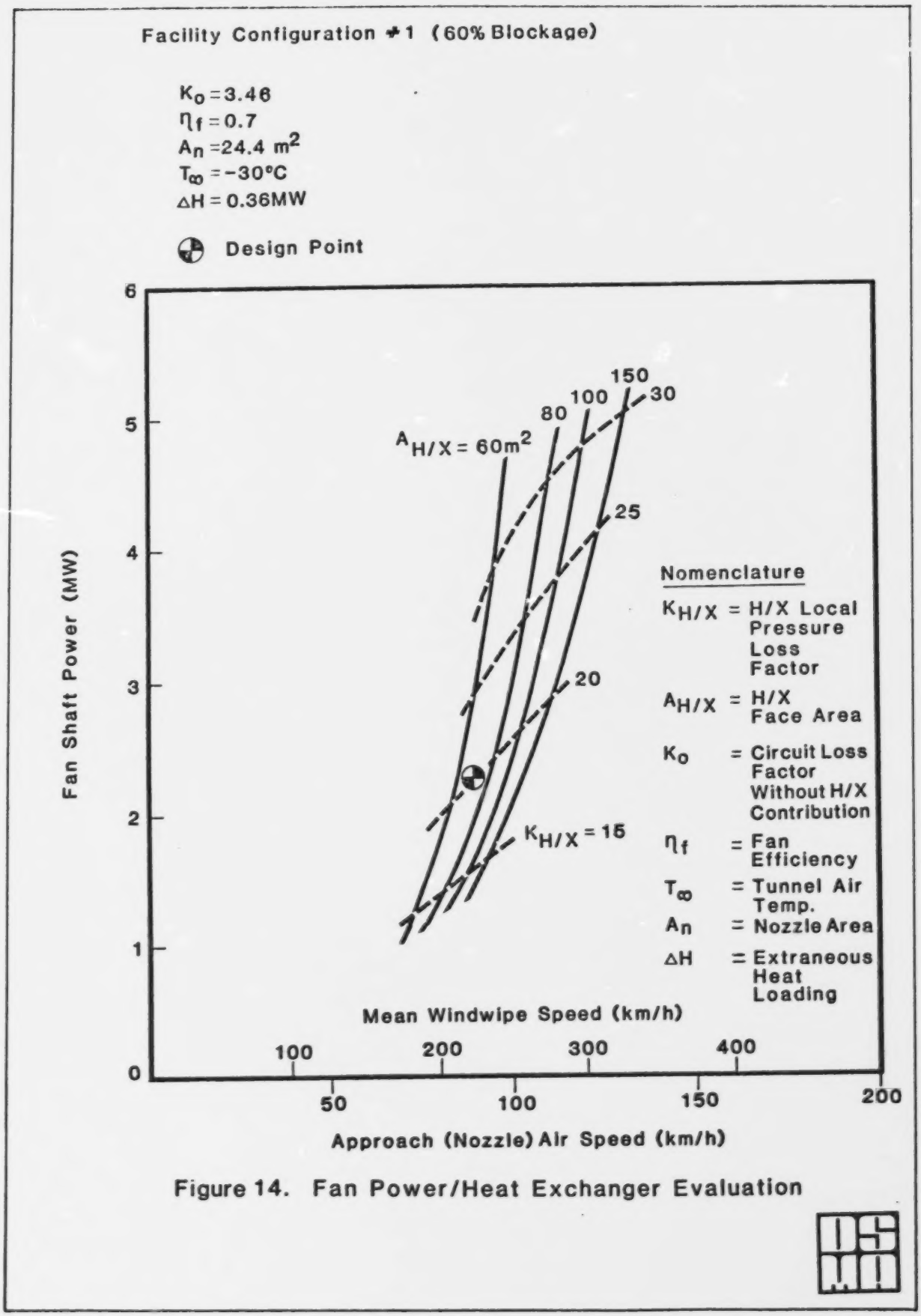


Figure 14. Fan Power/Heat Exchanger Evaluation

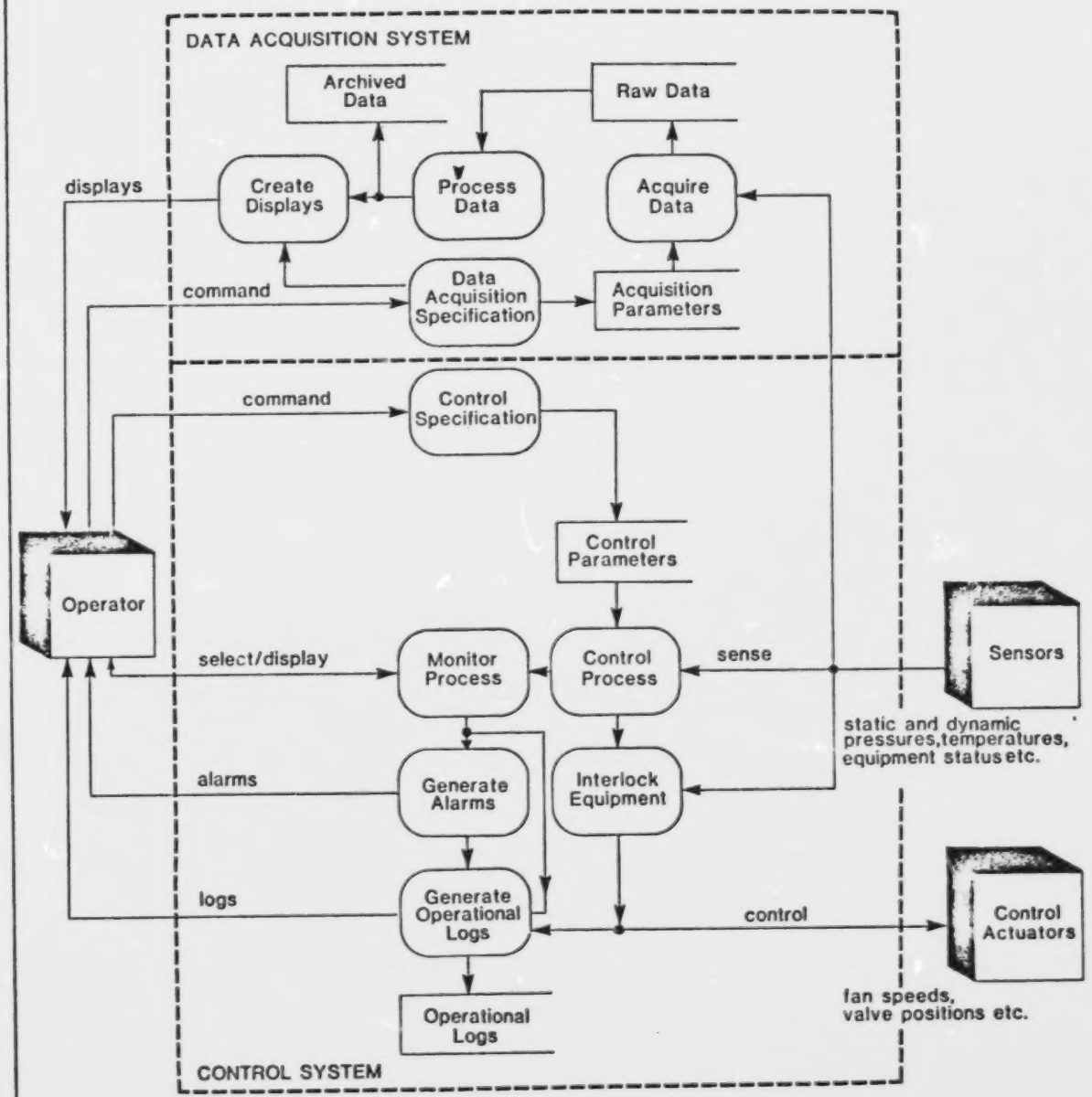


Figure 15 Facility Support System Schematic

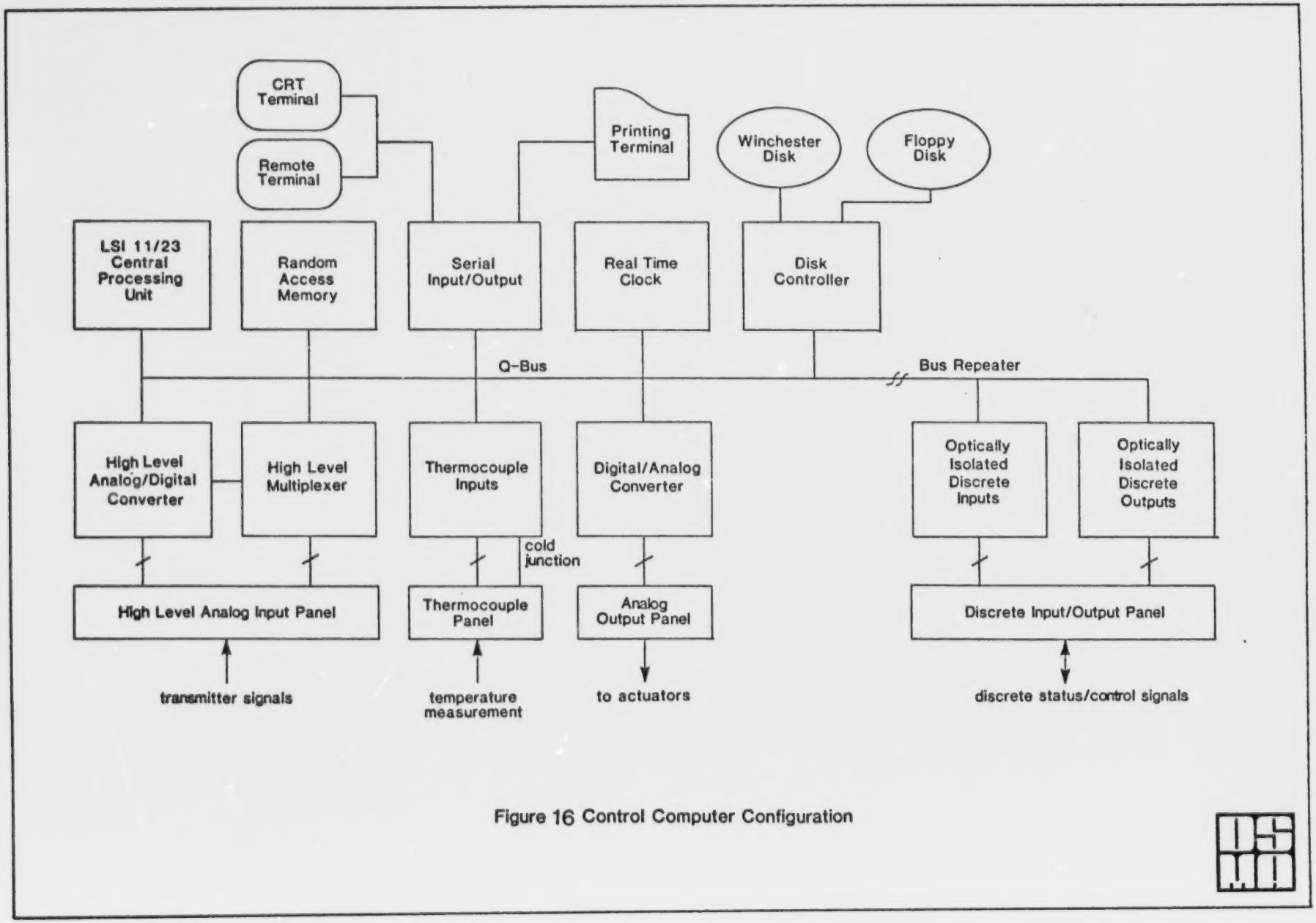


Figure 16 Control Computer Configuration

MIL-D-45123C(WC) PARA 3.4.1

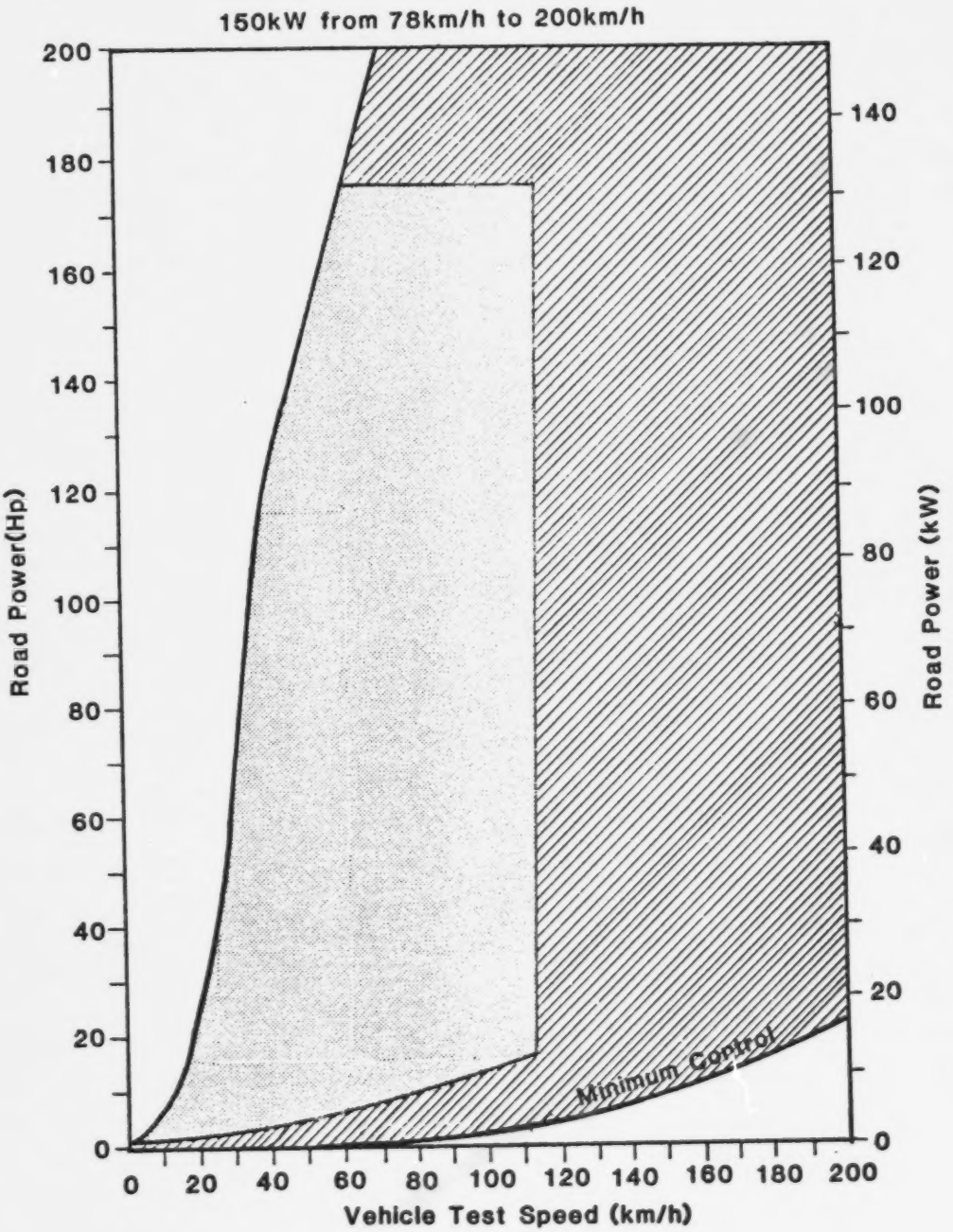
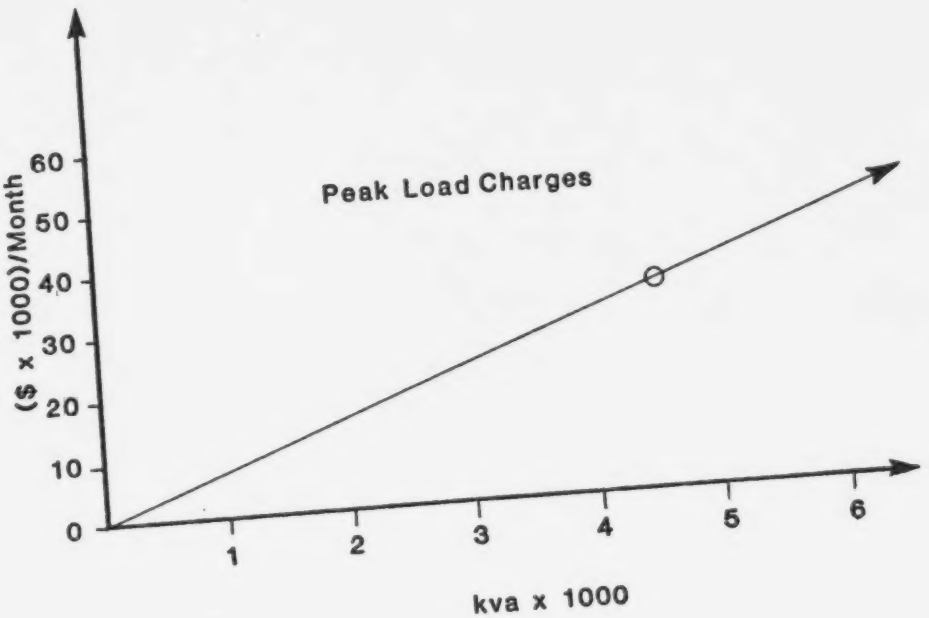


Figure 17. Clayton/AESI 150kW Absorber Load/Speed Profile



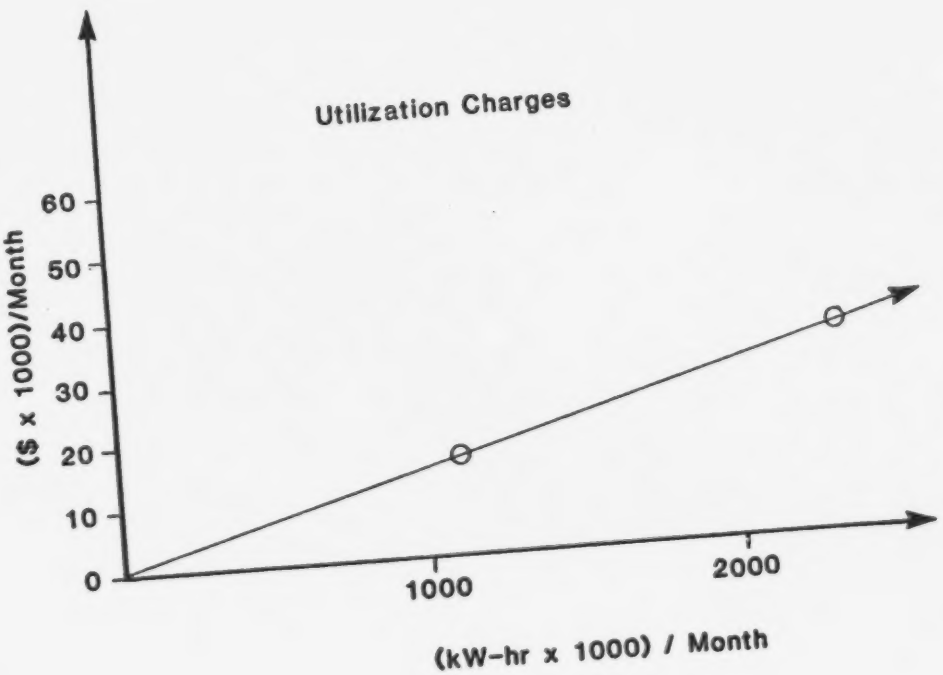


Figure 18. Electricity Cost Functions

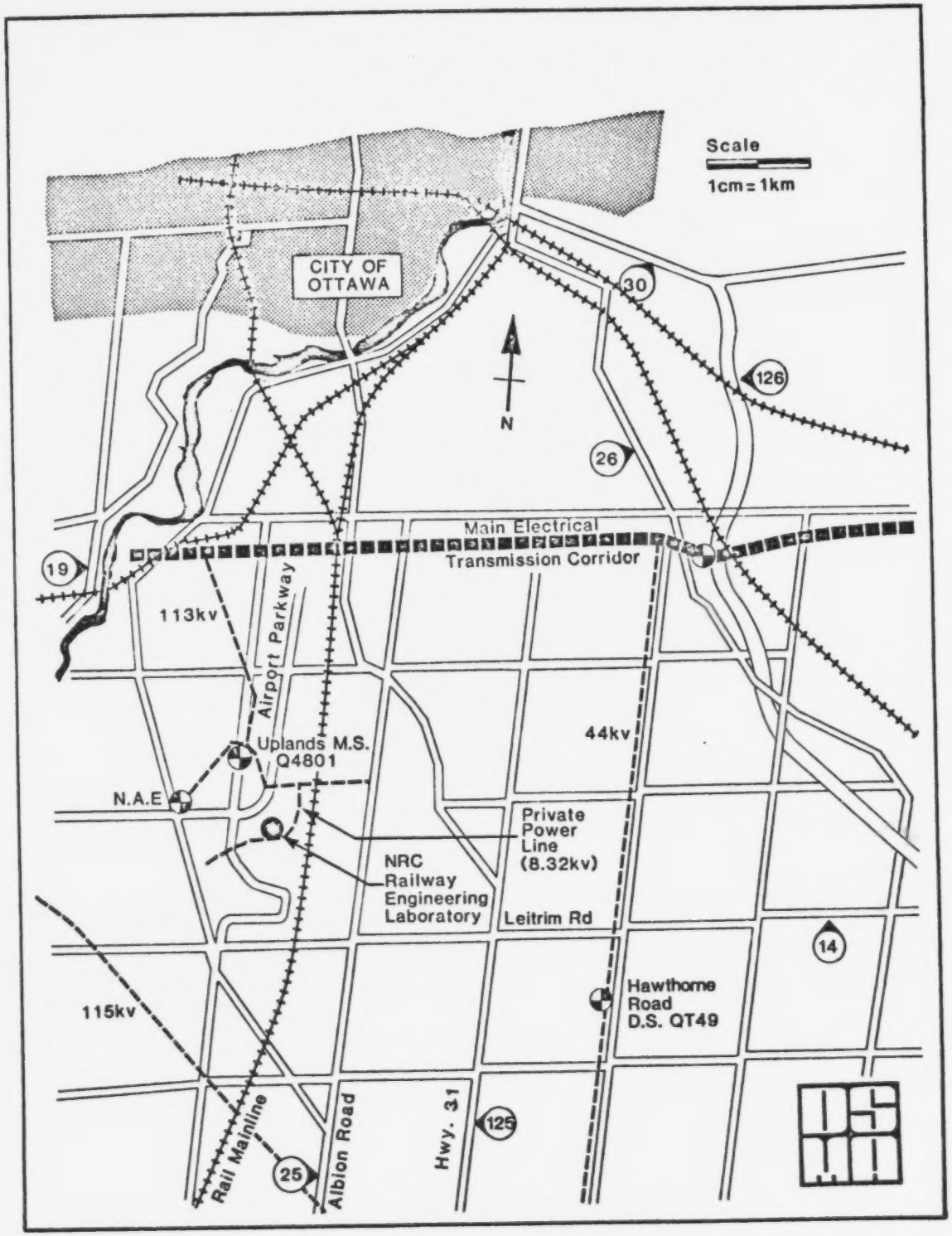


Figure 19. ELECTRICAL POWER SUPPLY ROUTE OPTIONS

TABLES

TABLE 1

INDUSTRY RESPONSES TO PRESCREENING QUESTIONNAIRE

Sector	Sent	Responses to Quest.1 Yes	No	Percentage Responding	Percentage of Respondents Who Said Yes	No. of Interviews
Road Transport	32	15	1	50	94	8
Off-Highway	38	27	2	76	93	9
Aerospace	12	8	2	83	80	2
Electrical	11	9	0	82	100	5
Railway	12	11	1	100	92	6
Marine	8	4	0	50	100	0
Petroleum, Mining and Materials Handling	23	8	4	52	67	0
Miscellaneous	4	0	0	0	0	0
TOTAL	140	83	10	66	89	30

Note: Question 1 on the prescreening questionnaire asked:

"Are any of your products subject to design constraints or operational problems as a result of exposure to adverse or varied climatic conditions?"

TABLE 2

FACILITY CONFIGURATION TEST SYSTEMS AND CAPABILITIES

Test System/Capability	Facility Configuration		
	1	2	3
Solid-Wall Test Section	X	X	X
Slotted-Wall Test Section		X	X
Humidity Control	X	X	X
Solar Simulation		X	X
Rain/Freezing Rain Simulation		X	X
Chassis Dynamometer			X
Air Make-up/Dehumidification			X
Vehicle Exhaust Extraction			X
Tunnel Purge System			X

TABLE 3

CASHFLOW ANALYSIS OF CONTROLLED CLIMATE TEST FACILITY (X$1000)

OPTIMISTIC SCENARIO - MINIMIZED OPERATING COSTS

	YEARS FROM START OF CONSTRUCTION											
	CONST1	CONST2	CONST3	4	5	6	7	8	9	10	11	12	13
CAPITAL COSTS													
CAPITAL COST	6917	6917	6917	0	0	0	0	0	0	0	0	0	0
TESTING ASSUMPTIONS													
MONTHS OF TESTING	0	0	0	2	2	3	3	4	4	4	4	4	4
HOURS PER DAY	0	0	0	8	8	8	8	8	8	8	8	8	8
DAYS OF TESTING	0	0	0	30	40	50	60	70	80	90	90	90	90
DAYS OF RESEARCH	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL DAYS IN USE	0	0	0	30	40	50	60	70	80	90	90	90	90
OPERATING COSTS													
OPERATING STAFF	0	0	0	25	25	25	25	25	25	25	25	25	25
MAINTENANCE STAFF	0	0	0	30	30	30	30	30	30	30	30	30	30
RESEARCH STAFF	0	0	0	72	72	72	72	72	72	72	72	72	72
REFRIG PLANT STAFF	0	0	0	56	56	56	56	56	56	56	56	56	56
DIRECT LABOUR	0	0	0	183	183	183	183	183	183	183	183	183	183
INDIRECT LABOUR	0	0	0	146	146	146	146	146	146	146	146	146	146
PEAK LOAD COSTS	0	0	0	462	462	485	485	528	528	528	528	528	528
HYDRO USAGE COST	0	0	0	26	35	44	52	61	70	78	78	78	78
HYDRO COSTS	0	0	0	488	497	539	547	589	598	606	606	606	606
MATERIALS AND SPARES	0	0	0	80	80	100	100	120	120	120	120	120	120
TOTAL OPERATING COST	0	0	0	808	808	868	877	1038	1047	1056	1056	1056	1056
TOTAL INVESTMENT	6917	6917	6917	808	808	868	877	1038	1047	1056	1056	1056	1056
REVENUE													
TESTING REVENUE	0	0	0	-60	-80	-100	-120	-140	-160	-180	-180	-180	-180
NET INVESTMENT	6917	6917	6917	838	828	868	857	898	887	876	876	876	876
OPER COST PER DAY	.0	.0	.0	27.8	20.7	17.4	14.3	12.8	11.1	9.7	9.7	9.7	9.7
NET PRESENT VALUE	6288	12004	17201	17814	18376	18923	19424	19908	20352	20758	21129	21468	21772

DSMA International Inc.

TABLE 4

CASHFLOW ANALYSIS OF CONTROLLED CLIMATE TEST FACILITY (X$1000)

INTERMEDIATE SCENARIO - MODERATE OPERATING COSTS

	YEARS FROM START OF CONSTRUCTION											
	CONST1	CONST2	CONST3	4	5	6	7	8	9	10	11	12	13
CAPITAL COSTS													
CAPITAL COST	6917	6917	6917	0	0	0	0	0	0	0	0	0	0
TESTING ASSUMPTIONS													
MONTHS OF TESTING	0	0	0	2	2	3	3	4	4	4	4	4	4
HOURS PER DAY	0	0	0	8	8	8	8	8	8	8	8	8	8
DAYS OF TESTING	0	0	0	30	40	50	60	70	80	90	90	90	90
DAYS OF RESEARCH	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL DAYS IN USE	0	0	0	30	40	50	60	70	80	90	90	90	90
OPERATING COSTS													
OPERATING STAFF	0	0	0	25	25	25	25	25	25	25	25	25	25
MAINTENANCE STAFF	0	0	0	30	30	30	30	30	30	30	30	30	30
RESEARCH STAFF	0	0	0	108	108	108	108	108	108	108	108	108	108
REFRIG PLANT STAFF	0	0	0	140	140	140	140	140	140	140	140	140	140
DIRECT LABOUR	0	0	0	303	303	303	303	303	303	303	303	303	303
INDIRECT LABOUR	0	0	0	242	242	242	242	242	242	242	242	242	242
PEAK LOAD COSTS	0	0	0	462	462	495	495	528	528	528	528	528	528
HYDRO USAGE COST	0	0	0	26	35	44	52	61	70	78	78	78	78
HYDRO COSTS	0	0	0	488	497	539	547	589	598	606	606	606	606
MATERIALS AND SPARES	0	0	0	80	80	100	100	120	120	120	120	120	120
TOTAL OPERATING COST	0	0	0	1114	1122	1184	1193	1254	1263	1272	1272	1272	1272
TOTAL INVESTMENT	6917	6917	6917	1114	1122	1184	1193	1254	1263	1272	1272	1272	1272
REVENUE													
TESTING REVENUE	0	0	0	-60	-80	-100	-120	-140	-160	-180	-180	-180	-180
NET INVESTMENT	6917	6917	6917	1054	1042	1084	1073	1114	1103	1092	1092	1092	1092
OPER COST PER DAY	.0	.0	.0	35.1	26.1	21.7	17.9	15.9	13.8	12.1	12.1	12.1	12.1
NET PRESENT VALUE	6288	12004	17201	17961	18658	19326	19938	20523	21059	21549	21995	22400	22769

TABLE 5

CASHFLOW ANALYSIS OF CONTROLLED CLIMATE TEST FACILITY (X$1000)

PESSIMISTIC SCENARIO - HIGH OPERATING COSTS AND LOW FEES

				YEARS FROM START OF CONSTRUCTION									
	CONST1	CONST2	CONST3	4	5	6	7	8	9	10	11	12	13
CAPITAL COSTS													
CAPITAL COST	6917	6917	6917	0	0	0	0	0	0	0	0	0	0
TESTING ASSUMPTIONS													
MONTHS OF TESTING	0	0	0	2	2	3	3	4	4	4	4	4	4
HOURS PER DAY	0	0	0	8	8	8	8	8	8	8	8	8	8
DAYS OF TESTING	0	0	0	30	40	50	60	70	80	90	90	90	90
DAYS OF RESEARCH	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL DAYS IN USE	0	0	0	30	40	50	60	70	80	90	90	90	90
OPERATING COSTS													
OPERATING STAFF	0	0	0	25	25	25	25	25	25	25	25	25	25
MAINTENANCE STAFF	0	0	0	30	30	30	30	30	30	30	30	30	30
RESEARCH STAFF	0	0	0	144	144	144	144	144	144	144	144	144	144
REFRIG PLANT STAFF	0	0	0	252	252	252	252	252	252	252	252	252	252
DIRECT LABOUR	0	0	0	451	451	451	451	451	451	451	451	451	451
INDIRECT LABOUR	0	0	0	361	361	361	361	361	361	361	361	361	361
PEAK LOAD COSTS	0	0	0	462	462	495	495	528	528	528	528	528	528
HYDRO USAGE COST	0	0	0	26	35	44	52	61	70	78	78	78	78
HYDRO COSTS	0	0	0	488	497	539	547	589	598	606	606	606	606
MATERIALS AND SPARES	0	0	0	80	80	100	100	120	120	120	120	120	120
TOTAL OPERATING COST	0	0	0	1380	1389	1450	1459	1521	1529	1538	1538	1538	1538
TOTAL INVESTMENT	6917	6917	6917	1380	1389	1450	1459	1521	1529	1538	1538	1538	1538
REVENUE													
TESTING REVENUE	0	0	0	-30	-40	-50	-60	-70	-80	-90	-90	-90	-90
NET INVESTMENT	6917	6917	6917	1350	1349	1400	1399	1451	1449	1448	1449	1448	1448
OPER COST PER DAY	.0	.0	.0	45.0	33.7	28.0	23.3	20.7	18.1	16.1	16.1	16.1	16.1
NET PRESENT VALUE	6288	12004	17201	18143	19005	19824	20573	21282	21931	22524	23063	23553	23989

DSMA International Inc.

TABLE 6

PRESENT VALUE OF INVESTMENT ($ X 1000) AT 10% REAL DISCOUNT RATE

Operating Cost Scenario	Facility Configuration		
	1	2	3
Optimistic	18,042	19,105	21,772
Intermediate	19,040	20,102	22,769
Pessimistic	20,270	21,332	23,999

NOTES:
1. Life of asset is 10 years after completion of construction.
2. Salvage value is assumed to be zero.
3. Other assumptions as per Tables 3, 4 and 5.

TABLE 7

CASHFLOW ANALYSIS OF CONTROLLED CLIMATE TEST FACILITY (X$1000)

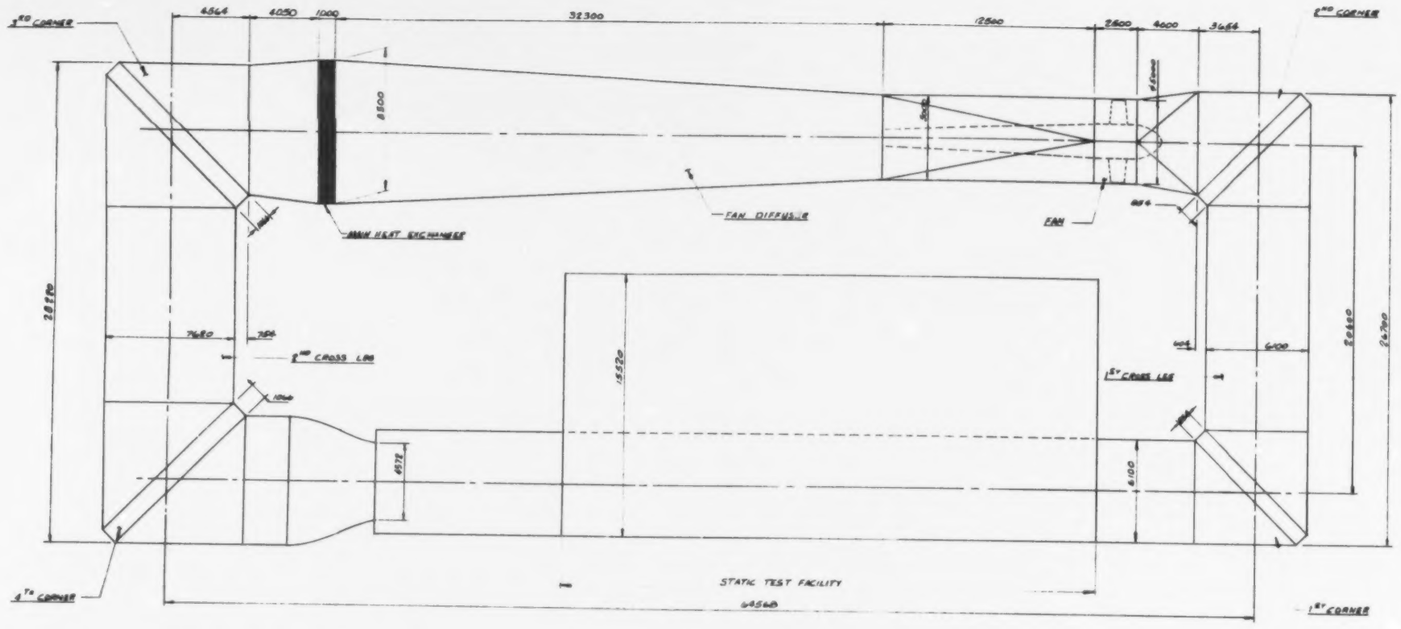
RESEARCH INTENSIVE SCENARIO - HIGH USAGE AND LOW OPERATING COSTS

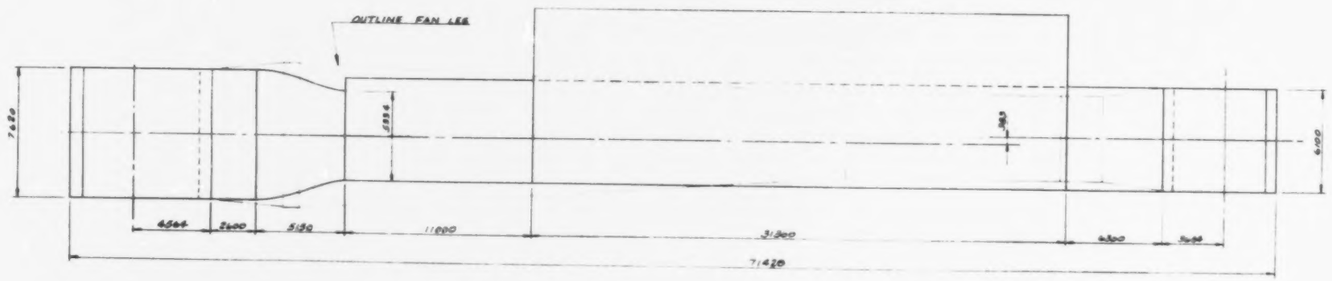
	YEARS FROM START OF CONSTRUCTION											
	CONST1	CONST2	CONST3	4	5	6	7	8	9	10	11	12	13
CAPITAL COSTS													
CAPITAL COST	6917	6917	6917	0	0	0	0	0	0	0	0	0	0
TESTING ASSUMPTIONS													
MONTHS OF TESTING	0	0	0	2	2	3	3	4	4	4	4	4	4
HOURS PER DAY	0	0	0	8	8	8	8	8	8	8	8	8	8
DAYS OF TESTING	0	0	0	30	40	50	60	70	80	90	90	90	90
DAYS OF RESEARCH	0	0	0	30	40	50	60	70	80	90	90	90	90
TOTAL DAYS IN USE	0	0	0	60	80	100	120	140	160	180	180	180	180
OPERATING COSTS													
OPERATING STAFF	0	0	0	25	25	25	25	25	25	25	25	25	25
MAINTENANCE STAFF	0	0	0	30	30	30	30	30	30	30	30	30	30
RESEARCH STAFF	0	0	0	72	72	72	72	72	72	72	72	72	72
REFRIG PLANT STAFF	0	0	0	56	56	56	56	56	56	56	56	56	56
DIRECT LABOUR	0	0	0	183	183	183	183	183	183	183	183	183	183
INDIRECT LABOUR	0	0	0	146	146	146	146	146	146	146	146	146	146
PEAK LOAD COSTS	0	0	0	462	462	495	495	528	528	528	528	528	528
HYDRO USAGE COST	0	0	0	52	70	87	104	122	139	157	157	157	157
HYDRO COSTS	0	0	0	514	532	582	599	650	667	685	685	685	685
MATERIALS AND SPARES	0	0	0	80	80	100	100	120	120	120	120	120	120
TOTAL OPERATING COST	0	0	0	924	941	1011	1029	1099	1117	1134	1134	1134	1134
TOTAL INVESTMENT	6917	6917	6917	924	941	1011	1029	1099	1117	1134	1134	1134	1134
REVENUE													
TESTING REVENUE	0	0	0	-60	-80	-100	-120	-140	-160	-180	-180	-180	-180
NET INVESTMENT	6917	6917	6917	864	861	911	909	959	957	954	954	954	954
OPER COST PER DAY	.0	.0	.0	14.4	10.8	9.1	7.6	6.9	6.0	5.3	5.3	5.3	5.3
NET PRESENT VALUE	6288	12004	17201	17832	18416	18987	19515	20027	20501	20938	21336	21697	22025

DSMA International Inc.

DRAWINGS

DWG. No. 4027 - 01





DWG. NO.	REFERENCE DWGS.

BILL OF MATERIAL

ITEM NO.	DESCRIPTION	MATERIAL	NOTE	QTY

Transportation Development Centre
Transport Canada

Dynamic Controlled-Climate Test Facility

DSMA International Inc.
Engineers and Constructors
Toronto, Canada

REVISION				

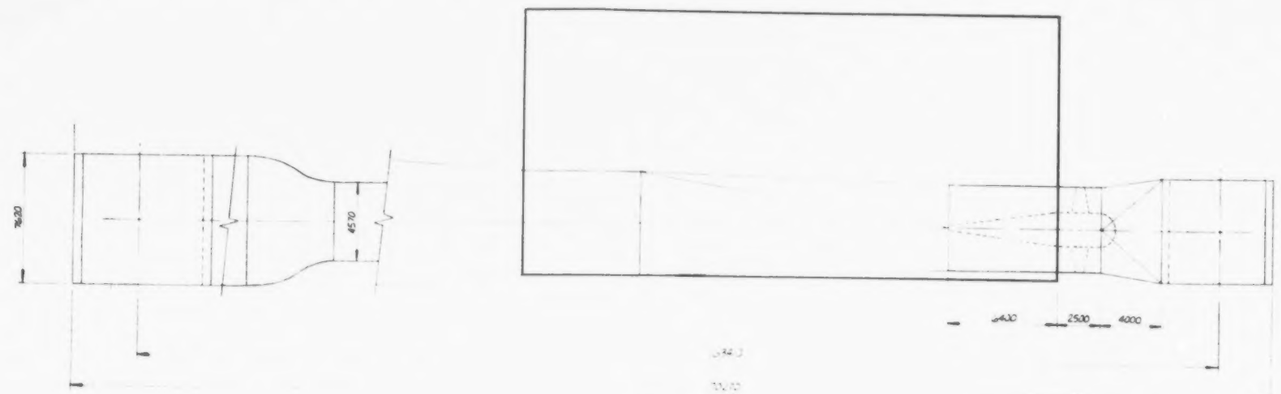
HORIZONTAL AIRLINE
(RECOMMENDED)

SCALE 1:100	SHEET OF
PROJECT 4027	SECTION
DWG. NO. 4027 - 01	REV. E

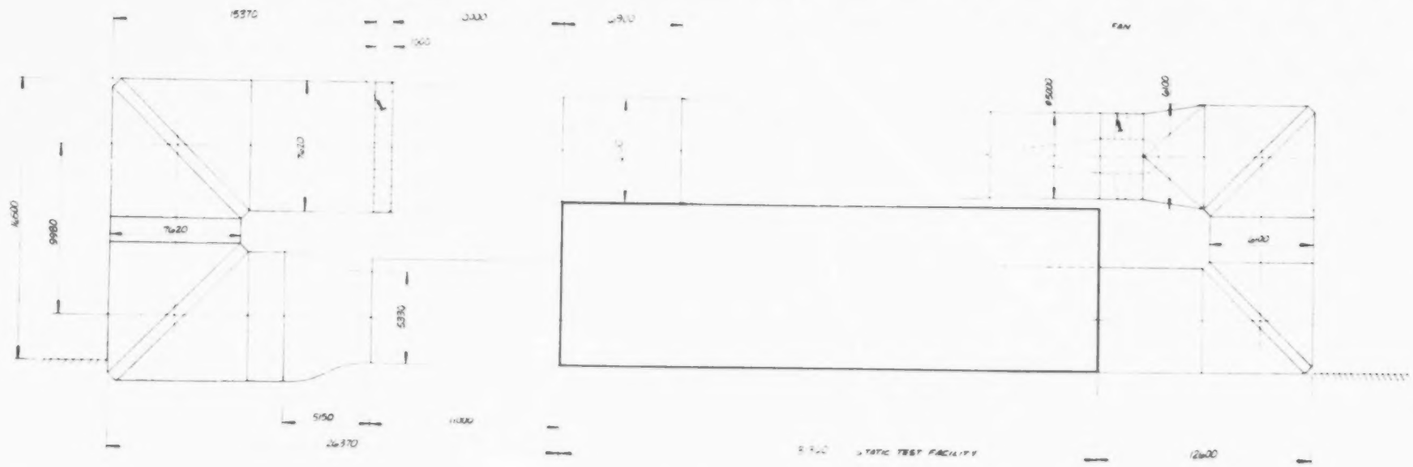
DWG. NO.	REFERENCE DWGS.

BILL OF MATERIAL

ITEM	QTY.	DESCRIPTION	MATERIAL	NOTE	WT.



PLAN



ELEVATION

Transportation Development Centre
Transport Canada

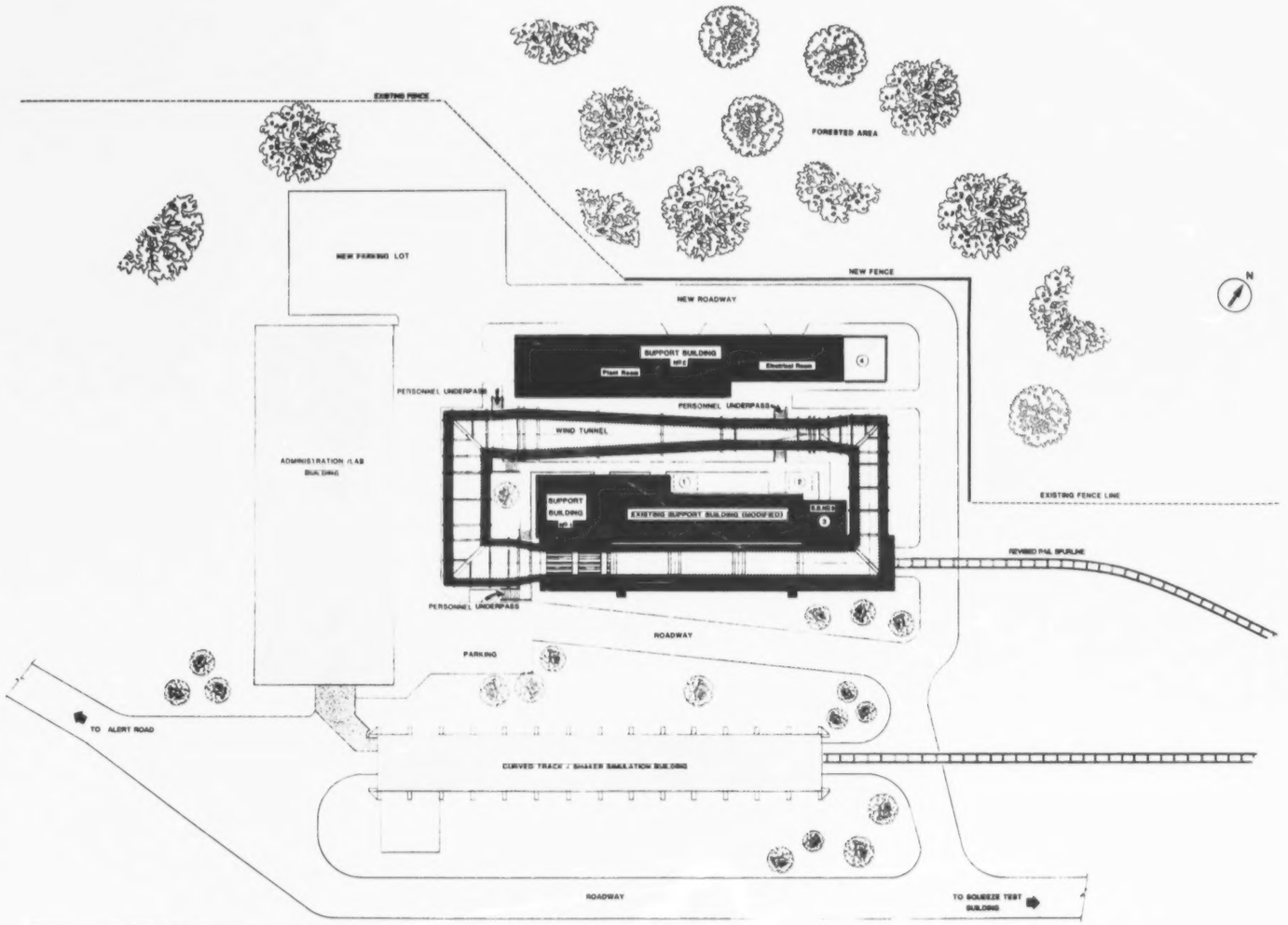
Dynamic Controlled-Climate Test Facility

DSMA International Inc.
Engineers and Constructors
Toronto, Canada

VERTICAL RETURN LOOP

SCALE 1:100				SHEET OF SHEETS
PROJECT 4027	SECTION	SUB-DIV. E	DWG. NO. 4027 - 02	ISSUE AS PER CHG.

DWG. No. 4027 - 03



Plant Room = 560 m² (360 m² without Dynamometer)
Electrical Room = 120 m²
Make-Up Air Room = 40 m² (only if Dynamometer Provided)

DWG. NO.	REFERENCE DWGS.

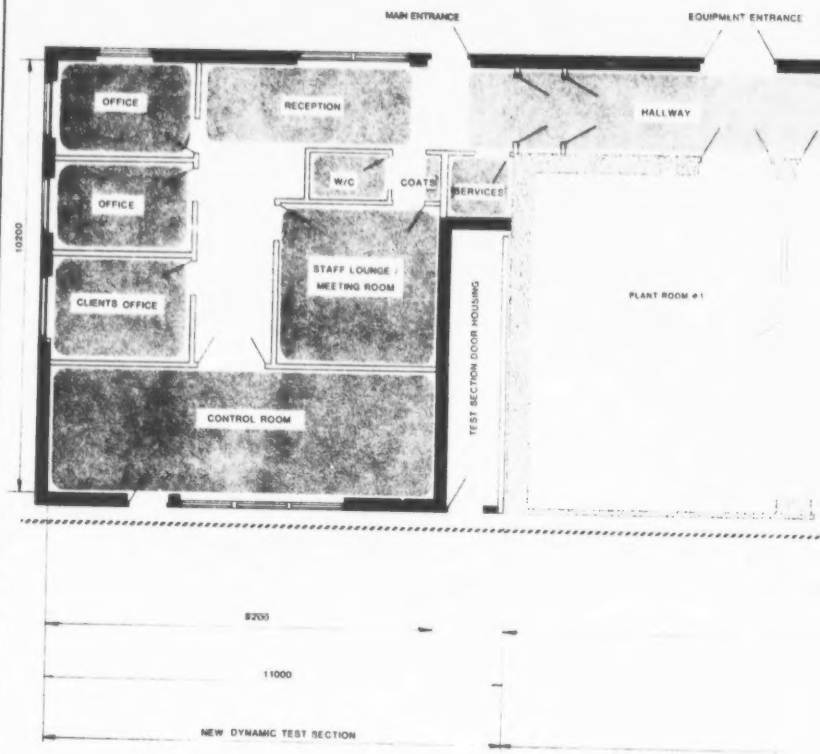
BILL OF MATERIAL

PIECE MK.	DESCRIPTION	MATERIAL	WGHT	QTY.

NOTES

1. Condenser Pad #1 (NRC Static Facility) - relocated
2. Condenser Pad #2 (NRC Static Facility) - existing
3. Support Building for Make-Up Air Unit (optional)
4. Main Transformer Sub-Station

E 4027 / 04



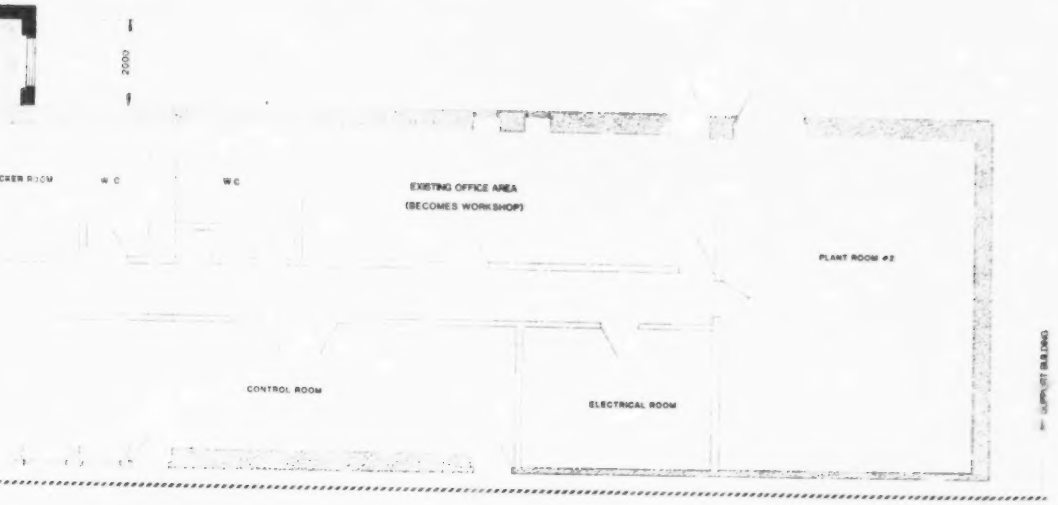
NEW OFFICE BUILDING : 84 m²

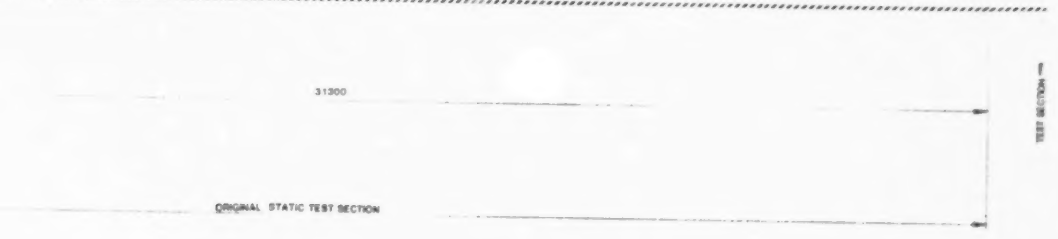
EXISTING BUILDING : 283 m²

DWG. NO.	REFERENCE DWGS.

BILL OF MATERIAL

ITEM	QTY	DESCRIPTION	MATERIAL	NOTE	QT





Transportation Development Centre
Transport Canada

Dynamic Controlled-Climate Test Facility

BY	As Drawn		
	REVISION		

PROJECTION: THIRD ANGLE

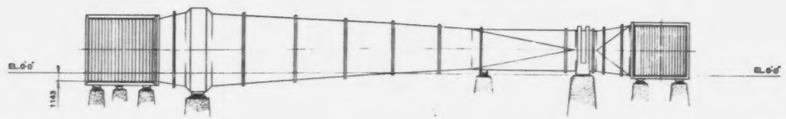
DESIGNED
DRAWN B. Tse
CHECKED
APPROVED

SUPPORT BUILDING PLOT LAYOUT

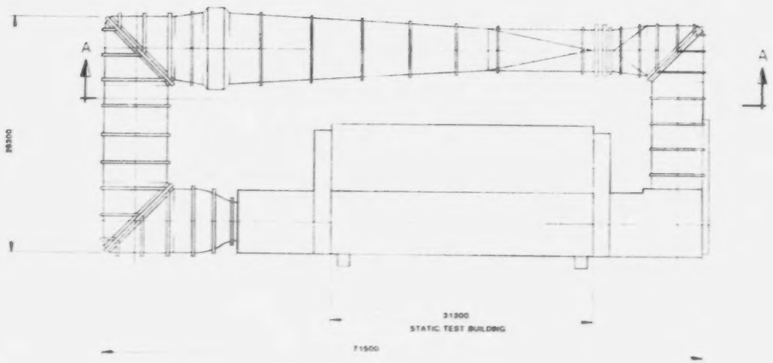
DSMA International Inc.
Engineers and Constructors
Toronto, Canada

SCALE 1:50	SHEET	OF	SHEETS
PROJECT 4027	SECTION	SIZE E	DWG. NO. 4027 / 04

DWG. NO. 4027 - 05



SECTION A-A



PLAN VIEW

SIDE ELEVATION

DWG. NO.	REFERENCE DWGS.

BILL OF MATERIAL

ITEM QTY.	DESCRIPTION	MATERIAL	WGT/U	U/I

Transportation Development Centre
Transport Canada

Dynamic Controlled-Climate Test Facility

REVISION				
E				

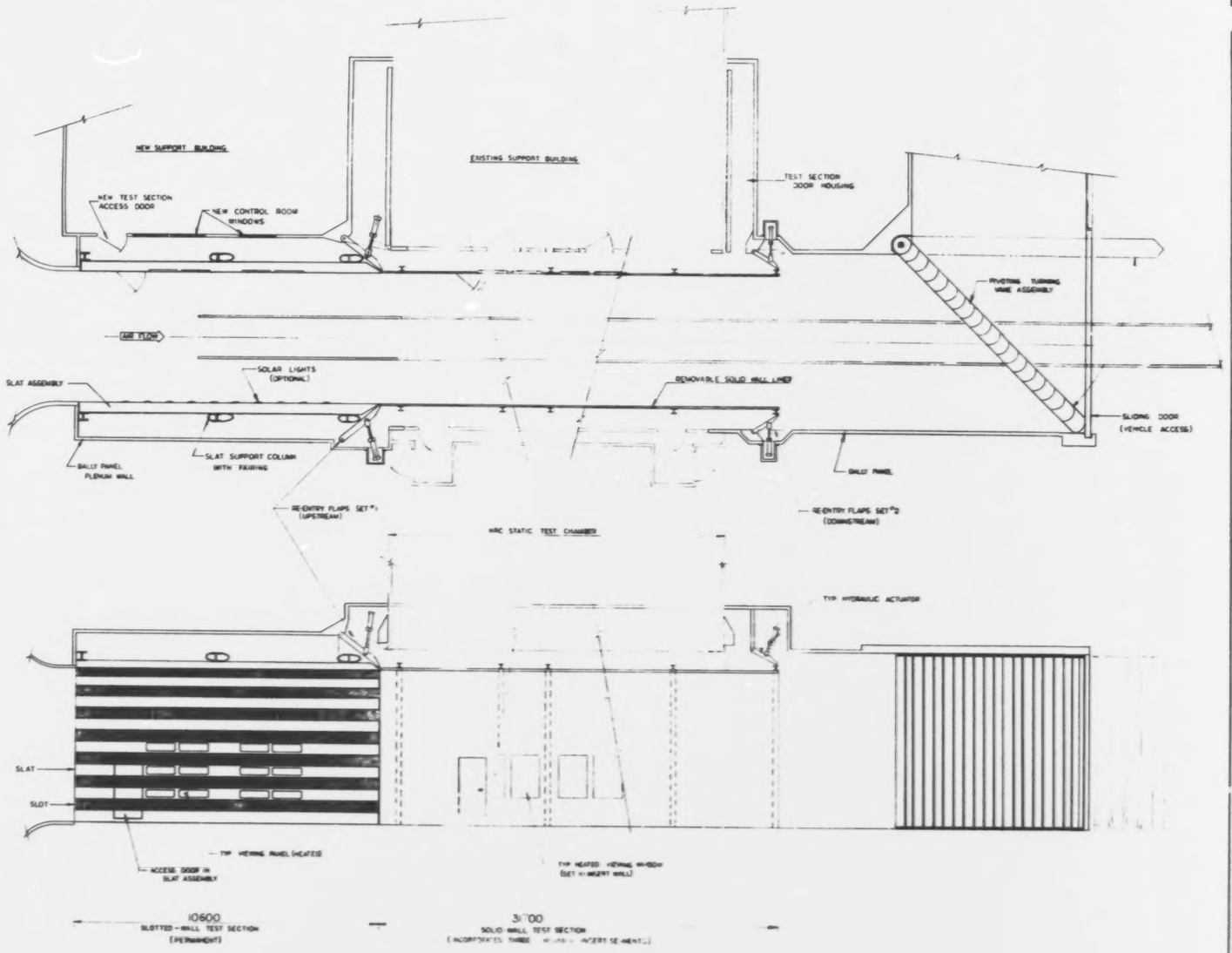
SHELL GENERAL ASSEMBLY

DSMA International Inc.
Engineers and Constructors
Toronto, Canada

SCALE 1:250			
PROJECT 4027	SECTION	SIZE E	DWG. NO. 4027 - 05

DWG. No. 4027 -08

E



DWG. NO.	REFERENCE DWGS.

BILL OF MATERIAL

ITEM NO.	DESCRIPTION	PART OR IDENT. NO.	MATERIAL	QTY

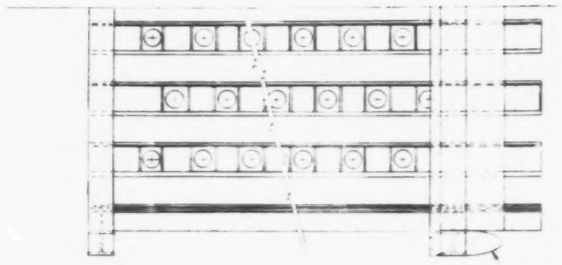
TEST SECTION
GENERAL ASSEMBLY
CONFIGURATION No. 2D

Transportation Development Centre
Transport Canada
Dynamic Controlled-Climate Test Facility

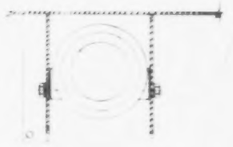
DBMA International Inc.
Engineers and Consultants
Toronto, Canada

SCALE	SHEET	SIZE	DWG. NO.	REV.
1:100	4027	E	4027 - 08	

E 4027 - 07



PLAN VIEW



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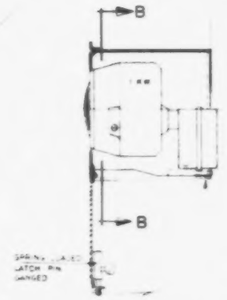
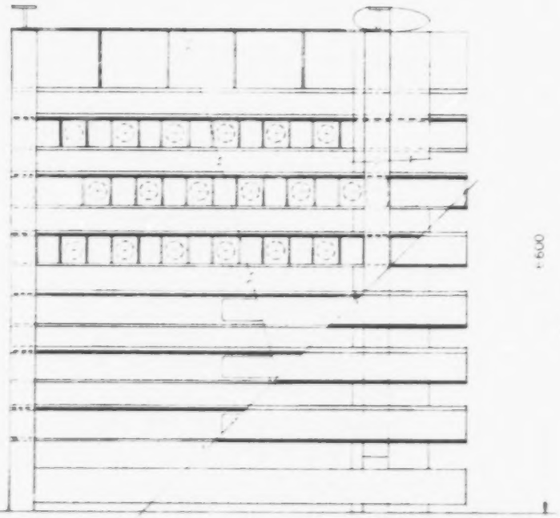
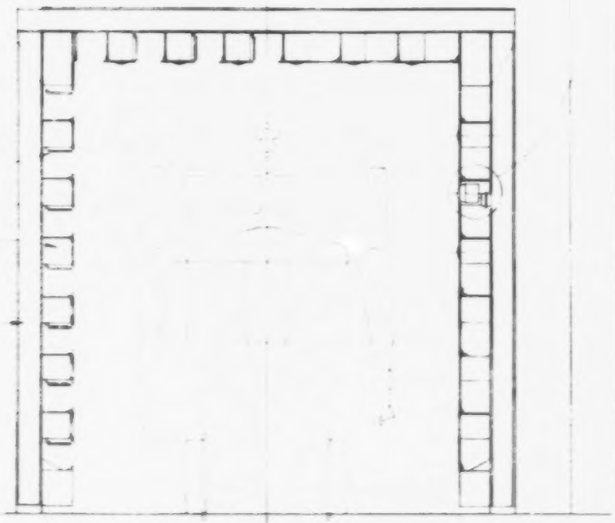


SOLAR SIMULATION (OPTIONAL)
LAMP MOUNTING SCHEME
SCALE 1:5



SIDE ELEVATION VIEW



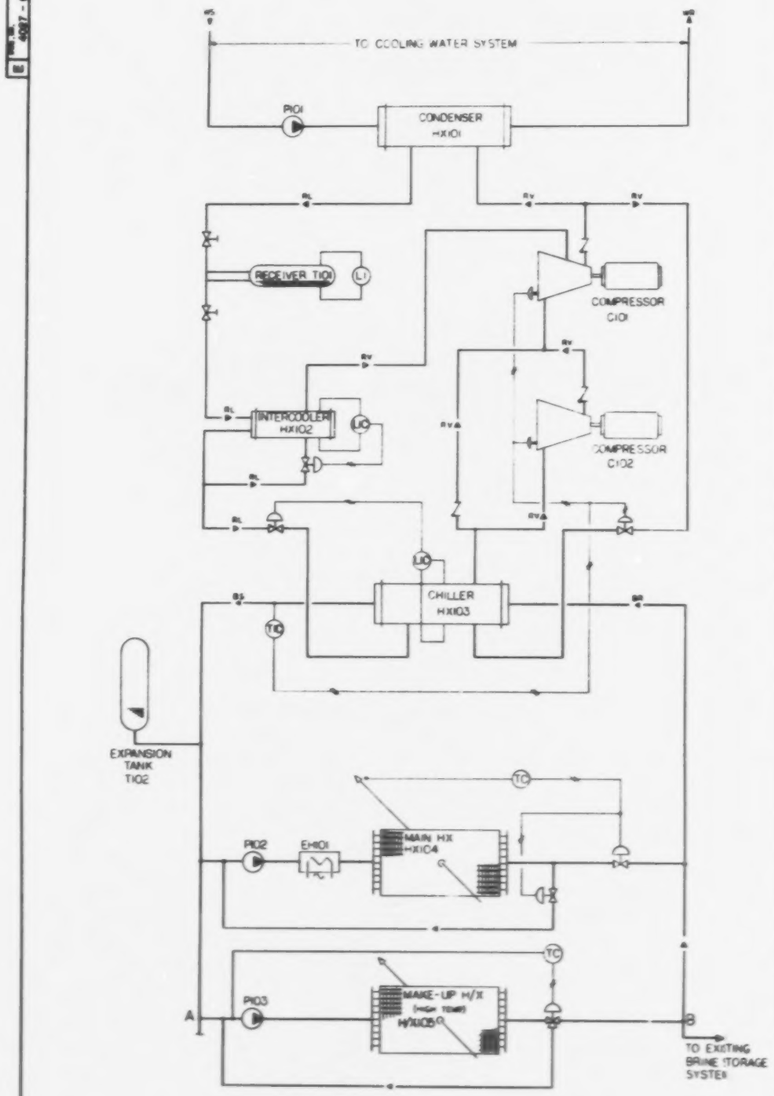
END VIEW
(LOOKING DOWNSTREAM)

NEW TEST SECTION
SLOTTED WALL ASSEMBLY
(CONFIGURATION N° 2)

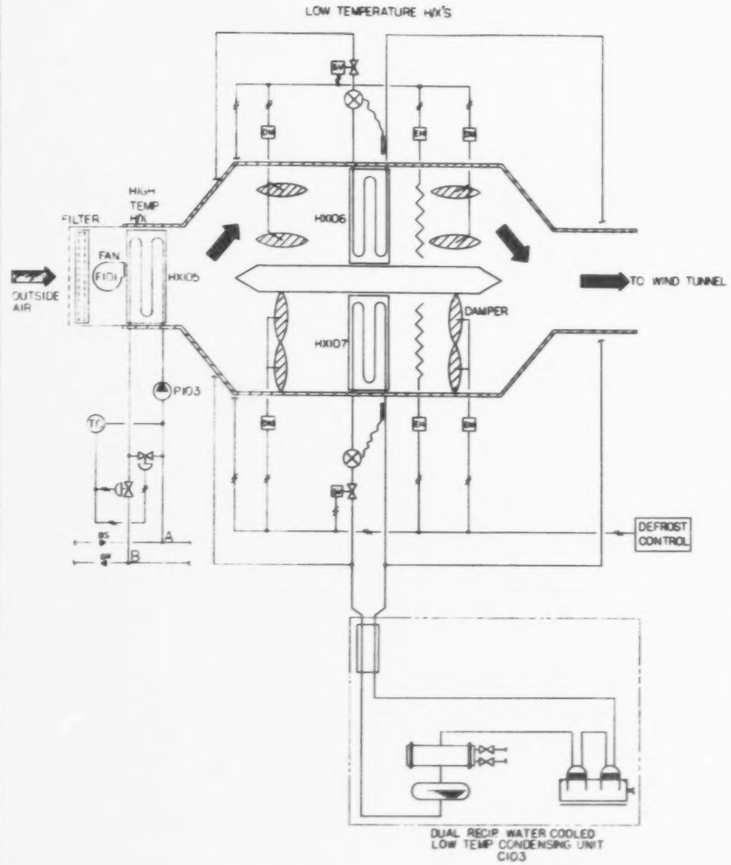
Transportation Development Centre
Transport Canada
Dynamic Controlled Climate Test Facility

DSMA International Inc.
Engineers and Constructors
Toronto, Canada

4027 | E | 4027 - 07



MAIN REFRIGERANT AND BRINE SYSTEM



MAKE-UP AIR SYSTEM

LEGEND

- WS (R) — WATER PIPING — SUPPLY (RETURN)
- RL (V) — REFRIGERANT PIPING — LIQUID (VAPOUR)
- BS (T) — BRINE PIPING — SUPPLY (RETURN)
- LIQUID PUMP
- MODULATING CONTROL
- INSTRUMENT CONTROL
- CHECK VALVE
- HAND VALVE
- AUTOMATIC VALVE
- HEATER
- 3-WAY AUTOMATIC VALVE
- THERMAL EXPANSION VALVE
- DAMPER MOTER

INSTRUMENT/CONTROL IDENTIFICATION

FIRST LETTER	OTHER LETTERS
T - TEMPERATURE	C - CONTROLLER
L - LEVEL	I - INDICATOR

SV - SOLENOID VALVE
EH - ELECTRIC HEATER

NOTES

Transportation Development Centre
Transport Canada
Dynamic Controlled-Climate Test Facility

COOLING SYSTEM
FLOW DIAGRAM

DSMA International Inc.
Engineers and Constructors
Toronto, Canada

4027 | E | 4027 - 08

Dwg. No. 4027-09

27.6 kv 3Ø4W Y

Main Substation

27.6 / 4.16 kv Transformer

Facility Configuration Ø1- 7500kva

Ø2- 7500kva

Ø3- 10000kva

Power Transformer

4.16kv 3 ph 60 HZ

4.16 kv Switchgear

Unit Substation

4.16 kv / 600 v Transformer

2500 kva (all)

4.16 kv / 600v

Isolating Transformer

3790 kva(all)

600v Switchgear

600v 3 ph 60HZ

Fan Drive System

Facility Configuration Ø1 2500kW

Ø2 2550kW

Ø3 2160kW

General MCC and

Power Distribution Centre

Ø1 650kW

Ø2 710kW

Ø3 720kW

Fan Auxiliaries MCC

200kva (all)

Refrigeration Low - Stage

Compressors and General MCC

Ø1 840kW

Ø2 840kW

Ø3 960kW

Refrigeration High - Stage Compressors

Ø1 1360kW

Ø2 1360kW

Ø3 2960kW

DWG. NO.	REFERENCE DWGS

BILL OF MATERIAL

ITEM QTY	DESCRIPTION	MATERIAL	WT'S	W

NOTES

1. Subsystem loads shown (kW) represent maximum individual loads for each subsystem under [illegible]

ELECTRICAL POWER

DISTRIBUTION SCHEMATIC

DSMA International Inc.

Engineers and Constructors

Toronto, Canada

4027 | E | 4027-09

APPENDIX I

USER SURVEY CONTACT LISTS

1. Canadian Federal/Provincial Governments
2. Industry
3. Canadian Universities

TABLE AI-1

CANADIAN FEDERAL/PROVINCIAL GOVERNMENT CONTACTS -

PRESCREENING QUESTIONNAIRE

No.	Agency	Contact/Title	Responded?
1.	Defence and Civil Institute of Environmental Medicine (DND)	Dr. Stuart Myles	Yes
2.	Land Engineering Test Establishment (DND)	Maj. Ken Lee, O.C. M Squadron	Yes
3.	Energy, Mines and Resources, Canada Centre for Mineral and Energy Technology	Mr. D.W.G. White, Mgr. Metal Development Lab	Yes
4.	National Energy Board	Mr. D. Foulger, Northern Pipelines Group	Yes
5.	National Research Council of Canada Mech. Engineering Division	Mr. T.R. Ringer, Manager, Low Temperature Laboratory	Yes
6.	Transport Canada, Motor Vehicle Test Centre	Mr. R.A. Malo, Head, Instrumentation	Yes
7.	Ontario Hydro	Mr. R. Muldoon, Energy Technology Development	Yes
8.	Hydro Quebec, Institute des Recherches	Mr. T. Gilsig, Directeur Adjoint	Yes

DSMA International Inc.

TABLE AI-1 (Cont'd)

No.	Agency	Contact/Title	Responded ?
9.	Industry, Trade and Commerce, Railway Division	Mr. M.B.P. Watson, Transportation Industries Branch	Yes
10.	Transport Canada, Strategic Studies	Mr. G.B. Maund, Chief, Energy Co-Ordination	Yes
11.	Environment Canada, Atmospheric Environment Service	Dr.J.D. McTaggert-Cowan, Co-Ordinator, Scientific Programs	Yes

TABLE A1-2

INDUSTRIAL CONTACTS - PRESCREENING QUESTIONNAIRE

ROAD TRANSPORTATION VEHICLES

REF	COMPANY NAME AND ADDRESS	CONTACT PERSON
TM-11	Western Star Truck Inc. 6205 Airport Road, Mississauga, Ontario	Peter Spytz, (416) 677-9800
	Western Star Truck Inc. 2076 Enterprise Way Kelowna, B.C., V1Y 6H8	G. Roziewski, Sr. Eng. Specialist (604) 860-3319
TM-12	Canadian Kenworth Truck Co., 3750 Kitchener Street, Burnaby, B.C., V5C 3L7	J. Rempel, Chief Engineer
TM-13	Mack Canada Inc., 302 The East Mall Islington, Ontario	J.F. Painter, Dir. Eng.
TM-21	Fruehauf Canada Inc. P.O.Box 1720, 2450 Stanfield Road, Mississauga, Ontario, L4Y 1S3	D. Grinstead, V.P. (416) 277-9511
* TM-43	Ford Motor Co. The Canadian Road, Oakville, Ontario	T.L. Johnson, National Service Mgr. (416) 845-2511 Ext. 1435
* TM-44	G.M. of Canada Whitson Road, Oshawa, Ontario	D.E. McLean, (416) 644-5301
TM-45	Chrysler Corp. of Canada 2450 Chrysler Center, P.O.Box 1621, Windsor, Ontario	M. Pfeiffer
* TM-63	Flyer Industries Ltd., 64 Hoka Street, P.O.Box 245, Transcona P.O. Winnipeg, Manitoba, R2C 3T4	W.E. Moss, Chief Engineer (204)224-1251
TM-71	Ontario Bus & Truck Industries Ltd. 5395 Haingate Dr., Mississauga, Ontario, L4W 1G6	D. Sheardown President (416) 625-9510

* Interviewed

REF	COMPANY NAME AND ADDRESS	CONTACT PERSON
* TM-89	Motor Coach Industries 1149 St. Matthews Ave., Winnipeg, Manitoba R3G 0J8	Geo. Schwarz, Mgr., Production Engineering (204) 786-3301
TM-91	Willock Industries Ltd., 1155 Park Street, Regina, Saskatchewan, S4N 4Y8	G. van Wachem
TO-106	Smith Transport Ltd., 150 Commissioners St. Toronto, Ontario, M5A 3R9	N. Arakgi, Dir. of Maintenance
TO-107	Lakehead Freightways Ltd., 774 Fort Street, P.O.Box 2058, Thunder Bay, Ontario	G.J. Smith, General Manager.
TM-108	Carrier Canada Limited 8100 Dixie Road, Bramalea, Ontario, L6T 2J8	Dan Lenover, National Sales Mgr. (416) 459-8000
TM-109	Thermo-King of Toronto 859 Westport Cres., Mississauga, Ontario, L5T 1E7	R. Ninnis, President.
TO-110	Provost Cartage Inc. 1900 Shawson Drive, Mississauga, Ontario L4W 1R7	L. Conway, Operations Mgr.
TO-111	Gray Coach Lines Ltd., 700 Bay Street, Toronto, Ontario	Mr. Porter, Operations Mgr. (416) 979-3531 Ext. 261
TO-112	Voyageur Colonial Ltd. Suite 404, 180 Dundas St. West, Toronto, Ontario, M5G 1Z6	H. Richer, Operations Mgr.
TM-120	Honda Canada Ltd., 715 Milner Street, Toronto, Ontario, M1B 2K8	T. Faulds, V.P. Serv. (416) 284-8110
TM-121	Toyota Canada Inc., 1291 Bellamy Road, N., Toronto, Ontario	P. Tschoepe, Ass. Nat'l Serv. Mgr. (416) 438-6320

ROAD TRANSPORTATION VEHICLES

REF	COMPANY NAME AND ADDRESS	CONTACT PERSON
TM-122	Nissan Automobile Company (Canada) Limited, Annacis Industrial Estate P.O. Box 2501, New Westminster , B.C. V3L 5A1	J. Black, (604) 526-4581
TM-123	Mazda Motors of Canada Ltd., 55 Milner Street, Toronto, Ontario	T. Shimada, V.P. (416) 291-2138
TM-124	Fiat Canada 1750 Brimley, Toronto, Ontario, M1P 3H2	Vittorio Venturi, National Technical Serv.Mgr., (416) 291-6493
TM-125	American Motors (Canada) Ltd., 350 Kennedy Road S., Brampton, Ontario	C. Raham, Res. Eng. (416) 451-6780
TM-126	Vapor Canada Limited, 3955 Courtrai Street, Montreal, Quebec.	
TM-129	Welles Corporation Ltd., 2650 Metcalfe Street, Windsor, Ontario, N8Y 4R5	D. Shields (519) 945-6311
* TM-130	Superior Bus Manufacturing Ltd., #10 - 1329 Niakwa Road, P.O. Box 460, Winnipeg, Manitoba, R2J 3T4	M. Wilkins, Chief Eng., (204) 257-4213
TM-131	Superior Propane Ltd., Motor Fuels Division, 1865 Leslie Street, Don Mills, Ontario	P. Smith, Mgr. Safety & Techn. Serv. (416) 444-7351
TM-132	Canadian Bluebird Coach Ltd., P.O. Box 880, Brantford, Ontario	B. Bankston, G.M. (519) 759-4960

REF	COMPANY NAME AND ADDRESS	CONTACT PERSON
* TM-133	Thomas Built Buses, Canada Limited, P.O.Box 580, 275 Tecumseh Street, Woodstock, Ontario, M4S 7Z5	L. Bannon, V.P. (519) 539-1226
TM-134	Prevost Car Inc., Rue Prevost St. Claire, Quebec, GOR 2VO	Jules Perreault, V.P. Engineering (418) 883-3391
* TM-136	Trailmobile Canada Ltd., 100 Shaver Street, Brantford, Ontario, N3T 5S2	D.J. Kennedy, President. A. Duda, Chief Engineer. (519) 758-4255

REF	COMPANY NAME AND ADDRESS	CONTACT PERSON
VM-14	International Harvester Canada 508 Richmond St. Chatham, Ontario N7M 5M4	N. Speller, Chief Engineer, (519) 356-1200 Ext. 261
* VM-15	Caterpillar of Canada Ltd. 1550 Caterpillar Rd., Mississauga, Ontario L4X 1E7	Geo. Ward, Quality Control Manager, (416) 297-9901
* VM-16	Euclid Canada Ltd., 200 Woodlawn Rd. W., Guelph, Ontario N1H 1B6	M.D. Etherington, Mgr. Product Eng., (519) 823-2000
* VM-17	King Seagrave Ltd., P.O.Box 187, Devonshire Ave., Woodstock, Ontario N4S 7X2	P. Brudnicki, Eng. Tech. (519) 537-6624
VM-18	Frink Canada Cambridge, Ontario	G. Jacquemain V.P. Man.
VM-19	Harnischfeger Corp. of Canada Ltd. 875 Progress Ave., Scarborough, Ontario M1H 3A7	L.L. Hagerman Regional Mgr.- Eastern Canada (416) 439-5500
VM-20	Massey-Ferguson Industries Ltd., 915 King St. W., Toronto, Ontario M6K 1E3	L.L. Gordon Chief Test & Development Engineer (416) 593-3690
VM-22	Pacific Truck & Trailer Ltd. P.O.Box 2084 Vancouver, B.C. V6B 3T2	Geo K. Boulet Mgr. of Engineering (604) 985-7121
* VM-23	Champion Road Machinery Group Ltd. Maitland Road, Goderich, Ontario N7A 3Y6	J. Turnbull Development Eng., Tom Powell, Chief Eng. (519) 524-2601
VM-24	WABCO Equipment of Canada Ltd., Paris, Ontario	A. Philp, Eng. Mgr.
VM-41	Bendix Heavy Vehicles Systems Group London, Ontario	Mr. Landrun, G.M.

REF	COMPANY NAME AND ADDRESS	CONTACT PERSON
* VR-46	Forest Engineering Research Institute of Canada (FERIC) Eastern Division 143 Place Frontenac Pointe Claire, Quebec, H9R 1G6	G.P. Chinn, Mgr. Eastern Div., Daniel A. Ljubic, Head Transportation Section (514) 694-1140
VR-47	Forest Engineering Research Institute of Canada (FERIC) Western Division 2112 West Broadway, Suite 201, Vancouver, B.C. V6K 2C8	G.V. Wellburn, Mgr. Western Division
VM-48	Allis Chalmers Canada Ltd. 347 Danforth Road, Scarborough, Ontario	B. Sawyer, Div. Manager
VM-49	Bombardier Inc., Recreational Products Div. Valcourt, Quebec, J0E 2L0	Guy Talbot (514) 532-2211 Ext. 238
VM-50	Heroux Limited 755 Thurber Longueil, Quebec	A. Brousseau (514) 679-5450
VM-51	Clarke Equipment of Canada Ltd. 25 Michigan Boulevard St. Thomas, Ontario, N5P 1H2	J. Meger (519) 631-9420
* VM-52	Timberjack Inc., P.O.Box 160, 925 Devonshire Ave., Woodstock, Ontario, N4S 7X1	Paul Whitcomb Mgr. of Engineering (519) 537-6217
VM-53	John Deere Welland Works Product Engineering Dept. Welland, Ontario, L3B 3N3	W.R. MacGregor Mgr. Product Engineering (416) 734-5401
VM-54	Hawker Siddeley Can. Inc. Can-Car Division 3160 Derry Road, East, P.O.Box 6001, Toronto, AMF, Ontario, L5P 1B3	R.A. Curmi (416) 677-3250 Ext. 324
VM-55	Hawker Siddeley Can. Inc., Canadian Car (Pacific) Div: 19433 - 96th Ave., P.O.Box 4200, Vancouver, B.C. V6B 4K6	D.K. McJunkin, Chief Engineer, (604) 888-1515

OFF-HIGHWAY VEHICLES

REF	COMPANY NAME AND ADDRESS	CONTACT PERSON
VM-56	Hawker Siddeley Can. Ltd., Forestry Equipment Division 3160 Derry Road, East, P.O.Box 1004, Malton, Ontario, L4T 3Y1	J.E. Umiker, Eng. Mgr. (416) 626-9220
VM-57	S. Madill Limited, P.O.Box 4300, 2560 Bowden Road, Nanaimo, B.C. V9C 5M6	Dale Siebert, Sales Mgr., (604) 758-5255
VM-58	Koehring Canada Limited, Koehring-Waterous Division P.O.Box 490 Brantford, Ontario, N3T 5P6	John Kurelek, V.P. Engineering, (519) 752-6571
VO-59	Pacific Logging Co. Ltd., Forestry and Logging Div., P.O.Box 10, 468 Belleville Street, Victoria, B.C. V8W 2M3	M.M. Mosher (604) 386-2171
VM-61	Farm King (1980) Ltd. P.O.Box 1003 50 Panet Road, Winnipeg, Manitoba, R3C 2W5	John E. Buhler, President, (204) 822-4467
VM-62	Atlas Hoist & Body Inc., 7500 Cote de Liesse Rd., Montreal, Quebec, H4T 1E8	M.M.Richler, President, (514) 341-6140
* VM-64	Canadian Co-Operative Implements Limited, 770 Pandora East, Winnipeg, Manitoba, R3C 3N1	Walter Warren, Director of Engineering (204) 224-1211
* VM-65	KHD Canada Inc., 4660 Hickmore Montreal, Quebec, H4T 1K2	W. Vossmeyer, V.P. J. Bass, Mgr. Special Projects (514) 735-4411
VO-66	MacMillan Bloedel Limited, Forestry Operations Research Section, 65 Front Street, Nanaimo, B.C., V9R 5H9	K.A. French, Research Director, (604) 254-5151

REF	COMPANY NAME AND ADDRESS	CONTACT PERSON
VO-67	Abitibi Paper Co. Toronto Dominion Centre, Toronto, Ontario, M5K 1B3	J.E. Tait, Mgr. Woodlands and Sawmills (416) 866-4280
VO-68	British Columbia Forest Products Limited, 1050 West Pender Street, Vancouver, B.C. V6E 2X3	G. Flater, Group V.P. - Pulp & Paper (604) 665-3803
VO-69	Consolidated Bathurst Inc., 800 Dorchester Blvd., W., Montreal, Quebec, M3B 1X9	D.A. Ackehurst, Mgr. Eng. Services (514) 875-2160
VO-70	Spruce Falls Power & Paper Co. Limited, P.O.Box 100, Kapuskasing, Ontario, P5N 2Y2	A. Buchanan, Wood Production Manager (705) 335-2311
VM-84	McKee Industries Ltd., P.O.Box 70 1 Industrial Road, Elmira, Ontario, N3E 2Z9	L. Heslop, Dir. of Prod. Planning, (519) 669-5115
* VM-86	White Farm Equipment Canada Ltd., 148 Mohawk Street, Brantford, Ontario, N3T 5R7	W.H. Scholich, V.P. Engineering (519) 752-7801
VM-100	Blackwood Hodge Equipment Ltd., P.O.Box 1004, Station 'A', Weston, Ontario, M9N 3N5	F.G. Mundy, V.P.
VM-101	FMC Canada Ltd., Crane & Excavator Division, P.O.Box 190, Woodstock, Ontario, N4S 7X3	D.E. Crabbs, Plant Mgr. (519) 539-9844
* VM-102	Versatile Farm Equipment Company 1260 Clarence Ave., Winnipeg, Manitoba, R3T 1T3	Warren Lenius, Mgr. Relability & Evaluation (204) 284-6100

REF	COMPANY NAME AND ADDRESS	CONTACT PERSON
* RO-1	Via Rail Inc, 2001 University Ave, Montreal, Quebec, H3A 2N2	T. Secord, Syst. Mgr. - Equipment Acquisition & Development, (514) 286-2311
* RR-2	C.N. Rail, Research Centre, 3950 Hickmore Ave., St. Laurent, Quebec, H4T 1K2	J.G. Lamont, Research Eng.
RO-139	Toronto Transit Commission Equipment Department 1900 Yonge Street, Toronto, Ontario, M5S 1Z2	D.A. Cowan, Mgr. Equipment Dept. (416) 481-4252
* RO-140	Commission de Transport de la Communaute Urbaine de Montreal 8845 Boulevard St. Laurent Montreal, Quebec, H2N 1M3	G. Beauchamp, Director Vehicle Maint. (514) 877-6300
RO-141	Ontario Northland Transportation Commission, 195 Regina Street, North Bay, Ontario P1B 8L3	K.J. Wallace, Sr. Director, Passenger Services & Planning, (705) 472-4500 Ext. 350
RO-142	Toronto Area Transit Operating Authority and Go-Transit Engineering and Maintenance Div., 3625 Dufferin Street, Downsview, Ontario, M3K 1Z2	C.S. Stradling, Mgr. Maint. Branch (416) 630-9984
RM-143	North American Car Corp. Canadian Railcar Division, 390 Bay Street, Toronto, Ontario, M5X 2Y2	(416) 366-7941
RM-144	Canadian Cardwell Co. Ltd., 1875 - 46th AVe., Lachine, Quebec, H8T 2N8	- -
RM-145	National Steel Car Corp. Ltd. 1155 Dorchester, W., Montreal, Quebec, H3B 2J2	J.W.Nelham, V.P. Sales, (514) 866-7461

REF	COMPANY NAME AND ADDRESS	CONTACT PERSON
* RO-146	CP Rail, Research Department Windsor Station Montreal, Quebec, H5A 1H4	A.E. Bethune, Dir. Technical Studies
* RM-147	Metro Canada Ltd./ UTDC Research & Development Ltd. P.O.Box 160, Station 'A', Kingston, Ontario K7M 6R1	C.B. Morris, Chief Test Eng. (MCL) Dr. J. Parker, V.P. Engineering (UTDC) (613) 389-9978
* RM-148	Bombardier Limited, Rail & Diesel Products Div., 1505 Dickson St., Montreal, Quebec, H1N 2H7	R.S. Bergner, Director Locomotive & Diesel Engine Development, (514) 253-7511
* RM-149	Bombardier Limited, Mass Transit Division 1350 Nobel Street Boucherville, Quebec. J4B 1A1	B. Clarke, Mgr. External Testing (514) 655-3830
* RM-151	General Electric Co., 2901-E Lake Rd., Bldg. 14-3 Erie, PA 16531	M. Loundes, Mgr.Domestic Mechanical Design (814) 875-3661

REF	COMPANY NAME AND ADDRESS	CONTACT PERSON
AM-32	DeHavilland Downsview, Ontario	J. Uffen, V.P. Eng.
AM-33	SPAR-Aerospace 1700 Ormont Drive, Toronto, Ontario M9L 2W7	E.R. Grimshaw, Dir. of Operations SPAR RMS Division
* AM-34	Bristol Aerospace Ltd., P.O.Box 874, 660 Berry St., Winnipeg, Manitoba, R3C 2S4	W.R. Bullock, V.P. Engineering, (204) 775-8331
* AO-35	Air Canada Air Canada Base 53, P.O.Box 9000, Montreal International Airport, Dorval, Quebec, H4Y 1C2	John C. Ohlsson Director Ground Equipment, Engineering (514) 636-2997
AM-36	Pratt & Whitney Aircraft of Canada Limited, 1000 Rue Marie Victorin, P.O.Box 10, Longueuil, Quebec, J4K 4X9	G. Hardy, Mgr. Development Eng. (514) 677-9411 Ext. 4275
* AM-87	Canadair Limited P.O.Box 6087, Montreal, Quebec, H3C 3G9	R. Regan, Mgr. Equipment Design. (514) 744-1511 Ext. 5445
AM-88	McDonnell Douglas Aircraft Canada Limited, P.O.Box 6013, Toronto, Cntario L5P 1B7	A.F. McMechan, Chief Materials & Process Eng. (416) 677-4341
AM-90	SMI Industries, Division of Caelter Ltd., 2055 Bennett Montreal, Quebec, H1V 2T3	Marc Riedl, Project Eng., (514) 255-2883
AM-99	Irvin Industries Canada Ltd., 479 Central Avenue, Fort Erie, Ontario, L2A 5M9	D.A. Wright,

REF	COMPANY NAME AND ADDRESS	CONTACT PERSON
AO-103	Okanagan Helicopters Ltd., 4391 Agar Drive International Airport South, Vancouver, B.C., V7B 1A5	D. McLean, V.P. Engineering
AM-118	Garrett Manufacturing Ltd. 255 Attwell Drive, Rexdale, Ontario, M9W 5B8	R.J. Richardson (416) 675-1411
* AM-135	C.D.N. Research & Development Ltd. 460 Wyecroft Road, Oakville, Ontario L6K 2G7	A.B. Stevens Mgr. Engineering (416) 842-2703

REF	COMPANY NAME AND ADDRESS	CONTACT PERSON
PO-25	Gulf Canada 2489 North Sheridan Way Sheridan Park, Mississauga, Ontario, L5K 1A8	D.D. Zakaib, Dir. of Tech. Operations, (416) 822-6770
PO-26	Shell Canada Ltd., Head Office Research, 550 University Ave., Toronto, Ontario	J.D. Cliffe, Co-Ord. Engine Fuels & Lubricants (416) 597-7782
PO-27	Petro-Canada Explorations P.O.Box 2844 Calgary, Alberta, T2P 3E3	R.T. McGrath, G.M.-Offshore and International Div. Production. (403) 232-8000
PO-28	ATCO Drilling Ltd., 1243 McKnight Blvd., N.E. Calgary, Alberta	J. Hlavka, V.P. Drilling.
PM-29	Dominion Bridge-Sulzer Montreal, Quebec	D. Kennedy, Mgr. of Eng.
PO-31	Foothills Pipelines (Yukon) Ltd., 1600-205 5th Ave, S.W Calgary, Alberta, T2P 2V7	Geo. B. Lipsett,P.Eng. V.P. Engineering. (403) 237-1042
PM-60	Forano Inc., 1600 St. Paul St. Plessisville, Quebec, G6L 2Y9	Guy E. Barre, (819) 362-7361
PO-72	Eldorado Nuclear Limited, 400-255 Albert Street Ottawa, Ontario, K1P 6A9	R.G. Dakers (613) 238-5222
PO-73	Falconbridge Nickle Mines Ltd, P.O.Box 40, Commerce Court West, Toronto, Ontario, M5L 1B4	M.A. Cooper, (416) 863-7000
PO-74	Noranda Mines Ltd., P.O.Box 45, Commerce Court West, Toronto, Ontario, M5L 1B6	J.C. White, V.P. Mines (416) 867-7111
PO-75	B.P. Explorations Canada Ltd., 333 5th Ave. Southwest Calgary, Alberta, T2P 1C9	J.S. Kazakoff, Mgr.- Oil & Gas Operations (403) 237-1234

REF	COMPANY NAME AND ADDRESS	CONTACT PERSON
PO-76	Kaiser Resources Ltd., 2600-177 West Hastings Vancouver, B.C., V6E 2L1	Roger Arscott (605) 681-9211
PT-77	Mining Industry Research Organization, P.O.Box 243, Commerce Court W., Toronto, Ontario, M5L 1B3	(Letter returned by P.O. - no forwarding address)
PR-78	Trans Canada Resources Ltd., 600-310 9th Ave. S.W. Calgary, Alberta, T2P 1K5	B.A. MacDonald (403) 269-7361
PO-79	Aquitaine Company of Canada Ltd., 555- 4th Ave., S.W. Calgary, Alberta, T2P 0M4	J. Payan (403) 2o7-9111
PO-80	Consumers Gas Co. Suite 4200, P.O.Box 90 First Canadian Place Toronto, Ontario, M5X 1C5	G. Kohli, Director Research, and Special Projects.
PO-81	Home Oil Company Limited, 2300-324 8th Ave., S.W. Calgary, Alberta, T2P 2Z5	R.F. Phillips (403) 232-1700
PO-82	Nabors Drilling Limited, 444- 7th Ave., S.W. Calgary, Alberta, T2P 0X8	D.A. Park, (403) 263-6610
PM-83	General Crane Industries Ltd., 670 Industrial Road, London, Ontario, N5V 1V1	R.A. Shuman, V.P. & G.M. (519) 453-1550
PM-85	Stephen-Adamson Division of Allis-Chalmers Canada Limited, P.O.Box 5900, 30 Franklin Belleville, Ontario K8N 5C8	D. Dibben Assist. Chief Eng. (613) 962-3411
PO-98	Esso Resources Canada Ltd., 339-50 Ave., S.E. Calgary, Alberta, T2G 2B3	R.D. Wards, Senior Research Eng.

REF	COMPANY NAME AND ADDRESS	CONTACT PERSON
PO-105	Panarctic Oils Limited 703- 6th Ave., S.W. Calgary, Alberta, T2P OT9	L.J. Franklin Operations Dept.
PO-138	B.C. Coal Limited P.O.Box 2000, Sparwood, B.C., V0B 2G0	(604) 425-8221

REF	COMPANY NAME AND ADDRESS	CONTACT
WM-30	Davie Shipbuilding Ltd., P.O.Box 130, Levi, Quebec	Mr. Rochette (418) 837-5841
WM-37	SPAR Marine Manufacturing Victoria, B.C.	V. Hearn, President.
WM-38	Georgetown Shipyard Inc. P.E.I.	H.M. Sutherland,
WM-39	Port Arthur Shipbuilding Co. Thunder Bay, Ontario	S.M. Thoms, V.P. & G.M. (807)683-6261
WO-40	Canada Steamship Lines Inc., 759 Victoria Square, Montreal, Quebec	D.R. Motion, Assist. Supt. Eng. (514) 288-0231 Ext. 338
WM-42	Collingwood Shipyards Div. of Canadian Shipbuilding & Engineering Collingwood, Ontario	A.S. Thoms Nav. Arch.
WM-104	Marine Industries Ltd., P.O.Box 550 Sorel, Quebec, J3P 5P5	Guy Veronneau, V.P. Shipbuilding & Repairs J.Y. Leblanc, V.P. hydraulic Gates
WM-113	Versatile Vickers Inc. 5000 Notre Dame St. E Montreal, Quebec, H1V 2B4	W. Nunn, Project Eng., (514) 256-2651

ENERGY CONVERSION EQUIPMENT AND OTHER INTERESTS

REF	COMPANY NAME AND ADDRESS	CONTACT PERSON
OM-116	Mulgrave Machine Works Co. Ltd. P.O.Box 100, Mulgrave, N.S.	J.C. Quinn
OM-117	Winflo (Canada) Limited 15-90 Esna Park Drive, Markham, Ontario L3R 2R7	P.E. Coulter
OM-137	ATCO Eastern Limited, 7213 Cordner, LaSalle, Quebec.	M. Langlois, G.M. (514) 363-4430

REF	COMPANY NAME AND ADDRESS	CONTACT PERSON
* EM-92	Canadian General Electric Co. Ltd., Power Delivery Department 201 Woodlawn Rd. W., Guelph, Ontario, N1H 1B8	K. Doughty Mgr. Design Practises (519) 822-2120
EM-93	Canadian Marconi Company 2442 Trenton Avenue, Montreal, Quebec, H3P 1Y9	Dr. J.W. Dodds
EM-94	Federal Pioneer Limited Winnipeg Research Department 101 Rockman Street, Winnipeg, Manitoba, R3T 0L7	P. Beck, Director R & D
* EM-95	Raytheon Canada Ltd., 400 Philip Street, Waterloo, Ontario, N2J 4K6	Mr. R.W. Dankwardt Mgr. Air Traffic Control (519) 885-0110 Ext. 254
EM-96	SED Systems Inc., Aerospace Products Division 2415 Koyl Avenue North, Saskatoon, Saskatchewan.	N. Foulds
EM-97	Westinghouse Canada Ltd., P.O.Box 510, 286 Sanford Avenue, N., Hamilton, Ontario, L8N 3K2	L.Hadenka, Q.A. Mgr. (416) 528-8811
EO-114	Ontario Hydro, Room H11-F01 700 University Ave., Toronto, Ontario, M5G 1X6	Bob Muldoon, Eng. Tech.-Development (416) 592-5586
EO-115	Hydro Quebec, Institute de Recherches D'Hydro-Quebec, (IREQ) 17 SE Place Dupuis Montreal, Quebec, H2L 4P5	Jean Laflamme, Chef de Service P.L.J. (514) 289-5089 A. Watts T. Gilsic, Directeur Adjoint. (514) 652-8011
EM-119	CAE Electronics Ltd., P.O.Box 1800, St. Laurent, Montreal, Que. H4L 4X4	C. Vandersluis, Mgr. Avionics Systems (514) 341-6780 Ext. 539

REF	COMPANY NAME AND ADDRESS	CONTACT PERSON
EM-127	Canadian General Electric Co. Limited Engineering Laboratory 107 Park Street North, Peterborough, Ontari, K9J 7B5	J.E. Benson, Mgr.-Engineering Lab. (705) 748-7729
EM-128	Canadian General Electric Co. Limited, Communications Systems Dept. Aerospace Unit, 396 Attwell Drive, Rexdale, Ontario, M9W 5C3	N. Regnier, Project Eng. (416) 675-7500 Ext. 247

REF	COMPANY NAME AND ADDRESS	CONTACT PERSON
MM-150	Bombardier Inc., Military Product Division Valcourt, Quebec, JOE 2LO	R. Renaud Director Quality Assurance (514) 532-2211

TABLE AI-3

CANADIAN UNIVERSITY CONTACTS - PRESCREENING QUESTIONNAIRE

No.	University	Faculty/Department		Name/Title	Responded?
1.	Acadia	Applied Science	(F)	G.D. Theothilus, Dean	No
2.a)	Alberta	Engineering	(F)	P.E. Adams, Dean	No
b)		Mech. Engineering	(D)	D.G. Bellow, Chairman	Yes
3.	British Columbia	Applied Science	(F)	L.D. Wedepohl, Dean	No
4.a)	Calgary	Engineering	(F)	J.H. Barton, Dean	No
b)		Civil Engineering	(D)	M.A. Ward, Head	Yes
5.a)	Carlton	Engineering	(F)	M.C. de Malherbe, Dean	No
b)		Geo-Tech Science Labs	(D)	P.J. Williams, Director	Yes
6.	Concordia (S.G.W.)	Engineering	(F)	M.N.S. Swamy, Dean	No

TABLE AI-3 (Cont'd)

No.	University	Faculty/Department		Name/Title	Responded ?
7.	Dalhousie	Engineering	(D)	D.M. Lewis, Chairman	No
8.a)	Lakehead	School of Eng'g	(D)	J.G. Locker, Director	No
b)		Centre for Regional Development	(D)	G.C. Harper, Exec. Dir.	Yes
9.	Laval	Ecole du Genie	(F)	L. Hout, Dean	No
10.	McGill	Engineering	(F)	L.W. Farnell, Dean	No
11.	McMaster	Engineering	(F)	J.W. Bandler, Dean	No
12.a)	Manitoba	Engineering	(F)	E.Kuffel, Dean	No
b)		Civil Engineering	(D)	A.M. Lansdown, Professor	Yes
13.a)	Memorial	Eng'g & Applied Science	(F)	C. de Cenzo, Dean	No
b)		Fac. of Medicine	(F)	J.W. Snellew, Professor	Yes

TABLE AI-3 (Cont'd)

No.	University	Faculty/Department		Name/Title	Responded ?
14.a)	New Brunswick	Engineering	(F)	F.R. Wilson, Dean	Yes
b)		Civil Engineering	(D)	A.N. Stevens, Professor	Yes
15.	Ottawa	Science & Eng'g	(F)	P. Moreand, Dean	No
16.a)	Queens	Applied Science	(F)	D. Bacon, Dean	No
b)		Cdn. Inst. of Guided Ground Transportation	(D)	C.E. Law, Exec. Director	Yes
17.	Saskatchewan	Engineering	(F)	P. Nikiforuk, Dean	No
18.a)	Toronto	Applied Science & Eng'g	(F)	G.R. Sleman, Dean	No
b)		Inst. of Aerospace Studies	(D)	R.C. Tennyson, Professor	Yes
c)		Mech. Engineering	(D)	R.D. Venter, Chairman	Yes
d)		Civil Engineering	(D)	Geo. Heinke Chairman	Yes

TABLE AI-3 (Cont'd)

No.	University	Faculty/Department		Name/Title	Responded?
19.	Nova Scotia Tech. College	Engineering	(D)	D.A. Roy	No
20.	Waterloo	Engineering	(F)	W.A. McLaughlin, Dean	No
21.	Western	Eng. Science	(F)	G. Chess, Dean	Yes
22.	Windsor	Engineering	(F)	C. MacInnis, Dean	No

APPENDIX II

USER SURVEY QUESTIONNAIRE

AND

INTERVIEW FORMS

APPENDIX II

TABLE OF CONTENTS

1. Industrial Prescreening Questionnaire Telex

2. Industrial Prescreening Questionnaire Follow-up Letter

3. Industrial Interview Checklist

4. University Prescreening Questionnaire and Covering Letter

TB/CT-REQB25022

ATTN: MR. A. NYBODY

DSMA INTERNATIONAL (A CANADIAN CONSULTING ENGINEERING FIRM) HAS BEEN AWARDED A CONTRACT BY TRANSPORT CANADA TO INVESTIGATE THE FEASIBILITY OF PROVIDING A LARGE-SCALE CANADIAN CLIMATIC TEST FACILITY (FOR VERIFICATION CONTACT TRANSPORT CANADA PROJECT OFF. R. NISHIZAKI (514)-283-4072).

TO THIS END, WE ARE SURVEYING CANADIAN INDUSTRIAL FIRMS TO DETERMINE THE IMPORTANCE OF CLIMATIC FACTORS (E.G. TEMP., HUMIDITY, RAIN, SNOW, ICE, SUN, WIND, ETC.) IN THE DESIGN AND OPERATION OF CANADIAN INDUSTRIAL PRODUCTS.

IT WOULD GREATLY ASSIST OUR EFFORTS IF YOU COULD ANSWER THE FOLLOWING SHORT LIST OF QUESTIONS. ALL INDIVIDUAL COMPANY ANSWERS WILL BE HELD IN STRICT CONFIDENCE. RESULTS WILL BE REPORTED IN AGGREGATE STATISTICAL FORM ONLY.

1. ARE ANY OF YOUR PRODUCTS SUBJECT TO DESIGN CONSTRAINTS OR OPERATIONAL PROBLEMS AS A RESULT OF EXPOSURE TO ADVERSE OR VARIED CLIMATIC CONDITIONS ?

   A. YES ____ (GO TO QUESTION 2)
   B. NO (EXPAND BRIEFLY)_____
   _____(GO TO QUESTION 5)

2. HAVE CLIMATIC CONDITIONS RESULTED IN:
   (INDICATE MORE THAN ONE IF APPROPRIATE)

   A. MECHANICAL FAILURES ? ____
   B. REDUCED PERFORMANCE ? ____
   C. REDUCED OPERATOR EFFICIENCY OR COMFORT ? ____
   D. ADJUSTMENT OF DESIGN OR SETTINGS TO CONFORM TO VARYING CLIMATIC CONDITIONS ? ____
   E. OTHER _____

3. HOW FREQUENTLY DO YOU INITIATE R & D ACTIVITIES RELATED TO CLIMATIC CONDITIONS ?

   A. REGULARLY ____
   B. OCCASIONALLY____
   C. NEVER ____

4. CLIMATIC R & D , WHEN CARRIED OUT, IS CONDUCTED IN:
   (INDICATE MORE THAN ONE IF APPROPRIATE)

   A. COMPANY-OWNED FACILITIES ____
   B. FACILITIES OWNED BY AFFILIATES ____
   C. INDUSTRY-SHARED FACILITIES ____
   D. FIELD TESTS ____
   E. GOVERNMENT FACILITIES ____
   F. PRIVATE CONTRACT TEST LABS ____

5. WHOM MAY WE CONTACT IN YOUR FIRM FOR FURTHER INFORMATION ?

   -NAME:
   -TITLE:
   -ADDRESS:
   -TELEPHONE:
   -TELEX:

IN VIEW OF THE POSTAL DISPUTE, RESPONSE BY TELEPHONE OR TELEX WOULD BE APPRECIATED. RESPONSES OF THE FORM: 1A,2B&D,3B,4C,J.DOE,ETC. WOULD BE ENTIRELY ADEQUATE.

PLEASE DIRECT RESPONSE TO DSMA INTERNATIONAL (ATTN: J.JACKSON)
4195 DUNDAS ST. W., TORONTO, ONTARIO, M8X 1Y4
TELEPHONE:(416)-239-3011 TELEX:06-967880

YOUR ASSISTANCE IN THIS SURVEY IS GREATLY APPRECIATED.

Industry Prescreening Questionnaire Telex

DSMA International Inc. Engineers and Constructors

4195 Dundas Street West, Toronto, Canada M8X 1Y4
Telephone (416) 239-3011/Telex 06-967880/Cable Address DSMACAN

REFERENCE: Transport Canada Controlled-Climate Test Facility
Telex Questionnaire

Thank you for taking the time to consider our questionnaire and providing us with an outline of your company's climate testing activities. The response rate to the questionnaire presently stands at about 35% - quite good considering the short period of time which has elapsed since its issue.

At this stage of our market survey, we are reviewing the questionnaire responses in order to select 25 or 30 prospects for detailed follow-up discussions. Anticipating a considerable amount of effort in co-ordinating schedules for these interviews, we have elected to send in advance an agenda for those discussions to all of the respondents. We hope that by providing this outline of discussion items, the companies interviewed will be given an opportunity to solicit views from within their organizations and to prepare a response.

There appears to have been some confusion created by the wording of our questionnaire with regard to the description of the proposed test facility as "large scale". To clarify, the test room of the facility is intended to be of large enough dimensions to accept machinery/systems up to the size of a railway locomotive. We are primarily looking for prospective facility users who require this type of test facility size and/or simulation capability.

We will be contacting selected respondents by telephone during the next two weeks to arrange interview dates. Should your company not be contacted by the end of October and you feel that your level of interest

in the use of the proposed facility warrants further discussions with us, please do not hesitate to get in touch. Alternatively, you might prepare a written submission based on the attached discussion agenda. We will maintain confidentiality with all information obtained during discussions or from written submissions.

We thank you once again for your interest and participation, and look forward to your further input in the study.

Yours sincerely,

John D. Jackson, P.Eng.,
Project Engineer

JDJ:am
Attach.

TRANSPORT CANADA CCTF MARKET SURVEY INDUSTRIAL INTERVIEWS

Date:

TABLE I
INVENTORY OF RESEARCH/TESTING CONCERNS
(Percentage of Total Climatic Testing Effort)

ITEM	CONTACT FILE, REFERENCE NO.
A1. Basic Research	
2. Standards Development	
3. Compliance Testing	
4. Product Development	
a) Reliability	
b) Maintainability	
c) Failure Analysis	
d) Performance	
e) Human Factors	
f) Energy Efficiency	
g) Cost Reduction	
h) Other	
B. Listing of Products Requiring Climatic Testing	

IN ATTENDANCE:

TRANSPORT CANADA CCTF MARKET SURVEY INDUSTRIAL INTERVIEWS

Date:

TABLE IIA

TEST SIMULATION REQUIREMENTS, CLIMATIC

ITEM	CONTACT FILE, REFERENCE NO.
1. a) Temperature, High (^{o}F) b) Temperature, Low (^{o}F) c) Temperature Resolution ($\pm\ ^{o}F$) d) Temperature Gradient ($^{o}F/hr$)	
2. a) Air Flow Velocity, Peak (mph) b) Air Flow Quality (% variation) c) Air Flow Velocity Resolution ($\pm$ mph)	
3. a) Humidity, High (%) b) Humidity, Low (%) c) Humidity, Resolution ($\pm$ %)	
4. Precipitation: a) Rain b) Snow (Type) c) Ice d) Freezing Rain e) Sand/Dust f) Other	
5. Solar Heating	
6. Ground/Soil Simulations (type)	
7. Other	

TRANSPORT CANADA CCTF MARKET SURVEY INDUSTRIAL INTERVIEWS

Date:

TABLE IIB TEST SIMULATION REQUIREMENTS, NON-CLIMATIC	
ITEM	CONTACT FILE, REFERENCE NO.
1. Dynamometer Capacity a) Absorbing (Hp) b) Motoring (Hp) c) Axle Load (lb) d) Wheel Speed, Max. (mph) e) Other	
2. Intake/Exhaust Ducting	
3. External Fuel Supply	
4. a) Data Acquisition System b) Data Processing System	
5. Controls Systems	
6. Vibration Studies	
7. Size of Largest Test Item a) Height (ft) b) Width (ft) c) Length (ft) d) Floor Loading	
8. Facility Access	
9. Preferred Locations: i) ii) iii)	

TRANSPORT CANADA CCTF MARKET SURVEY INDUSTRIAL INTERVIEWS

Date:

TABLE III

TESTING TASK RESPONSIBILITIES

ITEM	CONTACT FILE, REFERENCE NO. RESPONSIBILITY ASSIGNED TO:
1. Problem Identification	
2. Setting of Test Requirements	
3. Test Article Preparation	
4. Test Performance	
5. Test Supervision	
6. Data Collection	
7. Data Reduction	
8. Report Preparation	
9. Data Analysis	
10. Results Applications	
11. Other	

TRANSPORT CANADA CCTF MARKET SURVEY INDUSTRIAL INTERVIEWS

Date:

TABLE IV

EVALUATION OF TEST FACILITIES USED OR BEING USED

ITEM	CONTACT FILE, REFERENCE NO.	
	FACILITY 1	FACILITY 2
1. Facility Description: a) Name b) Location c) Administration d) Type of Simulation e) Total No. of Testing Days		
2. Facility Evaluation: a) Accessability b) Availability c) Size d) Test Capabilities e) Scheduling f) Cost ($/day) g) Administration h) Other		

TRANSPORT CANADA CCTF MARKET SURVEY INDUSTRIAL INTERVIEWS

Date:

TABLE V TESTING ADMINISTRATION, PLANNING AND VOLUME	
ITEM	CONTACT FILE, REFERENCE NO.
1. Testing Constraints: a) Internal Approval Procedures b) Affiliations c) Facility Location d) Budget, Costs e) Scheduling f) Other	
2. Level of Testing Effort: a) Past (days/year) b) Present (days/year) c) Planned (days/year) d) Potential(days/year)	
3. Testing Budget: a) Present ($/year) b) Planned ($/year)	

FURTHER CONTACTS:

DSMA International Inc. Engineers and Constructors

4195 Dundas Street West, Toronto, Canada M8X 1Y4
Telephone (416) 239-3011/Telex 06-967880/Cable Address DSMACAN

Dear Sir:

DSMA International and its affiliate, DSMA ATCON Ltd., have been contracted by Transport Canada's Transportation Development Centre to investigate the potential for a new, large, controlled-climate test facility in Canada. The facility would be sized to permit the testing of railway vehicles or equipment/systems of a comparable size.

As part of our investigations, a questionnaire has been sent to selected government agencies and private industries in order to initiate a survey of their climatic testing concerns. We feel that a poll of similar ongoing or planned research/development activities within the Canadian university community is also necessary to round out the initial stage of our market survey. An investigation of available listings of university research programs (through the National Research Council) has proved unsatisfactory, and attempts to find a standing inter-university committee who could handle our type of inquiry have been unsuccessful. It is, of course, impossible for us to contact each university researcher directly, so we have chosen to rely upon the administrative offices of the engineering faculties at each of the Canadian universities for distribution of our questionnaire.

I must stress that a facility of the type and size being considered would be suitable only for testing programs involving physically-large systems or equipment. Smaller-scale facilities are readily available for testing of small-size components or assemblies. If you are aware of any past, ongoing or planned climatic testing within your

engineering departments (or any other faculties, such as the Physical Sciences or environmental medicine), we would be most grateful if you would forward one of the attached questionnaires to the individual(s) involved. Their testing programs may be either government or industry-funded. Relevant climate simulation requirements might typically include temperature extremes, wind, humidity, precipitation and solar heating.

Our market survey tasks must be completed by the end of October 1981. For this reason, it is extremely important that responses from the universities be received as soon as possible if their requirements are to be reflected in the study results. Verification of our study and contract terms may be obtained through the Transport Canada project officer, Mr. Roy Nishizaki (Senior Development Officer, Transportation Development Center, 1000 Sherbrooke St. West, Montreal, Quebec, H3A 2R3; phone (514) 283-4072). We will be arranging follow-up interviews with some of the questionnaire respondents.

Thank you for your time and efforts in bringing our questionnaire to the attention of your associates.

Yours sincerely,

John D. Jackson, P.Eng.,
Project Engineer

JDJ:am
Attach.

Sept.1981

TRANSPORT CANADA CONTROLLED-CLIMATE TEST FACILITY STUDY

STUDY CONSULTANTS: DSMA International Inc.
DSMA ATCON Ltd.

MARKET SURVEY QUESTIONNAIRE

DSMA International and its affiliate, DSMA ATCON Ltd., (Canadian consulting engineering firms) have been contracted by Transport Canada's Transportation Development Center to investigate the feasibility of providing a new Canadian climatic test facility. The facility would be sized for the testing of railway rolling stock or equipment/systems of a similar size.

To this end, we are surveying the Canadian university research community (in addition to Canadian industry and government agencies) to determine the nature and extent of ongoing research and development activities requiring such a test facility. Our recommendations to Transport Canada on the design, location and organization of the facility will be based on the input received during our survey.

It will greatly assist our efforts if you would answer the short list of questions which follows. All answers will be held in strict confidence and will be reported in aggregate statistical form only.

1. Are you currently involved in, or do you plan any research or development projects directly concerned with the effects of exposure to adverse or varied climatic conditions?

   A. Yes ..... (Go to Question 2)

   B. No ..... (Please pass Questionnaire on to any relevant contacts you may be aware of)

2. Under which of the following categories do your investigations fall? (Indicate more than one if appropriate):

   A. Pure research

   B. Development of government or industrial standards

C. Product testing for legislative/standards compliance

D. Product development (eg. reliability, maintainability, failure analysis, performance, human factors, energy efficiency, cost reduction)

E. Other ..... (Please specify)

3. Which of the following best describes the current climatic test facility (or facilities) you employ? (Indicate more than one if appropriate):

A. University laboratory or facility

B. Government facility

C. Private-contract test facility

D. Industry facility

E. Field tests

4. How many days of climatic testing do you plan for (on a yearly basis) at present?

A. 1-5 days

B. 5-10 days

C. More than 10 days (Please specify)

5. Please describe briefly the type(s) of climatic testing you are currently involved in or have budgeted for (eg. low-temperature operation of mechanical equipment, environmental medicine, etc.):

.....

6. Please indicate the type of funding agency or company for the work referenced in Question No. 5. (Indicate more than one if appropriate):

A. National Research Council of Canada

B. Federal Government

C. Provincial Government

D. Private Industry

E. Other

7. Whom may we contact in your department for further details?

   - Name
   - Title
   - Department
   - University and Address
   - Telephone

Our market survey for Transport Canada must be completed by the end of October 1981; hence, a speedy reply is essential for incorporation in the results. Response by telephone or Telex is preferred, and need only be of the form: 1A, 2B & D, 3A, 4A, Machinery cold room testing, 6B, J. Doe, etc.

Please direct your reply to: Mr. John D. Jackson,
DSMA International Inc.,
4195 Dundas Street West,
Toronto, Ontario M8X 2Y4

Telephone: (416) 239-3011

Telex: 06-967880

Your assistance in this survey is greatly appreciated.

John D. Jackson

John D. Jackson, P.Eng.,
Project Engineer

APPENDIX III

USER SURVEY

SELECTED INTERVIEW SUMMARIES

1. Via Rail Inc.
2. Bombardier Ltd.
3. DND Land Engineering Test Establishment
4. NRC Low Temperature Laboratory

VIA RAIL INC.

September 15, 1981

Mr. T. Secord,
Manager, Equipment Acquisition and Development,
VIA Rail Inc.,
2001 Universitee
Montreal, P.Q.
H3A 2N2

---

1. John Jackson and V. Uzumeri met with Mr. Secord to discuss VIA's requirements for controlled-climate testing at VIA's Montreal head office.

2. Mr. Secord started by reviewing VIA's perceived requirements for a test facility. He was well acquainted with the study through previous contacts with the Canalog Study. His stated requirements were as follows:

   - $+40^{o}C$ to $-40^{o}C$, $+ 1^{o}C$
   - up to 100% humidity
   - rain simulation
   - freezing rain simulation
   - icing studies
   - dust simulation
   - dynamometer simulation, perhaps by loading the locomotive motor electrically
   - wind speeds to 240 km/h
   - if no wind simulation, need greater temperature range to simulate "windwipe"
   - air flow is needed to test aerodynamics for energy conservation, and would be aimed at design studies in the following areas:

     - leading edge
     - gaps between cars
     - under-car air flow
     - shape of intakes and stacks

   - floor loading for vehicle weights of up to 145000 kg.

3. VIA feels that rolling stock should be tested by the supplier in the first instance, but VIA has only one maintenance facility and no backing or redundancy, so reliability is a problem. Currently, tests have been carried out on components at:

   - National Research Council
   - Westinghouse Air Brake, Stoney Creek (3 m x 3 m x 6 m cold room)
   - Galley Mfg. (hot room)
   - Ontario Research Foundation

4. Mr. Secord identified areas where VIA felt more research and/or testing are required:

   - low temperature failure and performance
   - high temperature
     - controls
     - refrigeration
     - door opening systems

   - energy loads and power consumption - on many trains, the train length is limited by the locomotive auxiliary power units' capacity to service cars, rather than by locomotive tractive power
   - testing LRC
   - possible future lubricants testing
   - changing (generally lowering) of fuel quality and use of alternative fuels
   - trend to increasing water content in diesel fuel
   - low-temp starting of diesels
   - heated drain lines
   - braking systems - ice between brake shoe and wheel
   - freezing of air lines in brake systems
   - restarting warm engines with cold intake air
   - fuel tank heating

5. VIA Rail currently is involved in a variety of testing. In tests where it is involved, VIA generally identifies problems, sets requirements and applies results, but does not perform the actual tests.

6. VIA views current NRC lab as being suitable, subject to its physical size limitations. Specifically, Mr. Secord had the following observations:

   - good accessibility
   - acceptable availability; VIA can live with 2-3 mo. lead time for testing
   - good data reduction capability
   - good price

7. VIA's view of the Budd facility closely reflects the experience of Bombardier, from whose tests their views were derived:

   - good accessibility at a high price (i.e. the cost of setting up in Philadelphia)
   - long way from manufacturing facilities if re-testing required
   - availability is dicey since Budd can bump contract tests
   - Budd room is a little short for easy testing
   - cold limited to -20°C and requires a long time for stabilization (presoak to -20°C is 4.5 days)
   - all cold tests must be performed first, then the warmer ones

- Budd didn't have enough recorders/sensors
- client can bring in own equipment
- adequate provision of cranes and jacks
- inspection pit available

8. VIA Rail has no problem with approval procedures. Among its criteria for choosing facilities are the concerns for location and support staff.

9. Mr. Secord felt that whatever facility is developed by the Canadian government, it should adhere to the following criteria:

   - it should aim to decrease fragmentation of testing in railway industry
   - it should not involve an entirely new organization (i.e. should be under aegis of NRC)
   - the industry is doing about half the climatic testing it should be doing
   - the facility should be designed for capability to carry out compliance testing

10. VIA Rail would be prepared to go on a retainer basis for 6 weeks of test facility time per year.

11. Possible additional contacts include:

    - Door Suppliers: Faveline, Vapor, Stone Platt
    - Toilets: Vapor, Sloan Valve., WABCO

RM-148
RM-149
September 14, 1981

BOMBARDIER INC.
MASS TRANSIT AND RAIL AND
DIESEL PRODUCTS DIVISIONS

Mr. Robert Bergner
Director, Locomotive & Diesel Engine Development
Rail and Diesel Products Division
1505 Dickson Street,
Montreal, Quebec.
(514) 253-7333

---

1. Discussions were held at the offices of Transport Canada with Mr. B. Clarke of the Bombardier Mass Transit Division, R. Nishizaki (TDC), W.McLaren (TDC) and V. Uzumeri (DSMA) in attendance. Mr. Archambault of the Recreational Vehicles Division and Mr. Cole of the trucking division were not able to attend.

2. Bombardier's concerns regarding environmental testing were divided into two major categories: locomotives and passenger rail cars.

Passenger Rail

3. Mr. Clarke indicated that passenger railcars now cost approximately $1 million each, of which 50% is labour, and are extremely labour intensive to repair. It is thus a company policy to perform climatic tests on prototypes as early in the product development process as Bombardier can manage.

4. Bombardier performs all of its product design and development in response to the customer's requirements as defined in the vehicle specification. As a result, Bombardier is not conducting an evolutionary product development function; rather it changes its technology and approach on a contract-by-contract basis.

5. Bombardier's testing is done once during the design process and can be scheduled well in advance. Any problems encountered after the scheduled tests are completed must be corrected by an adjustment or retrofit in order to meet schedule and cost constraints. Bombardier has never retested a vehicle and does not intend to do so in the future.

6. Concerns with environmental design of passenger cars center on design with new materials, passenger comfort and power consumption.

7. The LRC cars are almost totally aluminum. Experience is limited with this technology and unexpected problems have occurred. Thermal expansion and contraction for example, have resulted in measured changes in length of 2.5 cm in a 29 m car. Other new materials include lucite ceiling interior panels which initially sagged under high temperatures (38°C).

8. Door systems may stick and overload motors at temperature extremes due to varying materials properties. Water systems may freeze, since there is a lot of piping in a typical vehicle and complete protection is often difficult due to restricted space.

9. Passenger comfort places constraints which affect the trade-off between vehicle weight and insulation.

10. Passenger train length is typically limited by the ability of the locomotive's auxiliary power unit to supply passenger cars operating needs, rather than by locomotive's tractive power. Current limit is approximately 10 passenger cars per locomotive. Power consumption is clearly affected by heating and cooling loads.

11. Bombardier currently tests its passenger cars at the facility of the Budd Co. in Philadelphia. The facility has the following advantages and disadvantages:

    Pro: - Budd personnel are specialists in rail vehicle testing and can prepare the test report.

    - It is only facility currently large enough to accommodate passenger vehicles.

    Con: - Budd is a direct competitor of Bombardier's.

    - Fee is $75,000 per 3 week session, in addition to Bombardier's manpower costs and the costs of transporting vehicle to Philadelphia (including custom clearances).

    - Facility is only a basic climate chamber. There is no movement of air except by local fans.

12. Bombardier feels that any alternative facility should have the following capabilities.

    - ability to accommodate a 5.5 m x 26 m x 3.4 m coach
    - $-40^{o}C$ to $+43^{o}C$
    - high movement of air around vehicle (160- 200 km/h)
    - easy access for power cables and large DC power supply
    - data acquisition and reduction system
    - capability to accept different wheel gauges
    - good insulation
    - specialist group in charge
    - location in eastern Canada
    - solar heat loading
    - all information gained should have restricted access
    - snow and ice simulation, if possible

13. With regard to the need for a dynamic facility, Mr. Clarke was enthusiastic. He felt that several areas required greater investigation:

- effect of 'wind wipe' on heat balance tests
- effect of air movement on air intakes and air inlets

Mr. Clarke felt that traditional railway rule-of-thumb adjustments were of dubious accuracy.

14. Bombardier has tested one new vehicle design per year in each of the last two years at the Budd facility. The testing has been in response to increasingly strict user specifications. Mr. Clarke expected that Bombardier would test at least two vehicles per year in each of the next two years. Since each test takes approximately 1 month, this translates into 2 months of dedicated testing time per year.

15. Testing time is so long because rail vehicle mass may require several days to cool down or heat up fully. This is due primarily to the mass of metal in the vehicle's undercarriage and suspension.

16. In general, Mr. Clark was enthusiastic about the value of climatic testing in vehicle development and was convinced that Bombardier was similarly committed. Dissatisfaction with the Budd arrangement is such that a Canadian alternative would receive considerable support.

Railway Locomotives

17. The locomotive development effort was also interested in climatic testing, but not to the same degree as the passenger vehicle development effort.

18. MLW-Bombardier locomotives are sold in Canada and exported. Yearly production capability is between 50 and 100 locomotives.

19. All of the research in locomotive development is applied research. Bombardier is now executing a program to develop a new Canadian locomotive design. The program is funded at $54 million, with the involvement of Industry, Trade and Commerce, and is split into two major activities: diesel engine development and locomotive chassis development.

20. Climatic testing has considerable impact on the locomotive design. In particular, the following design issues require consideration of climatic conditions:

- snow ingestion in air inlets, traction motors and apertures in general
- noise generation by the air handling system
- wind wipe problem with combustion-air inlet

21. Actual testing of locomotive performance under varied climatic conditions has previously been performed during field tests. Mr. Bergner felt that purchasers were most impressed with testing performed on their property. Tests in climate chambers are likely to be specified more frequently in future North American procurements, but are not yet a common practice.

22. Locomotives designed for export to third world countries are not subject to significant climatic performance requirements, except in engine cooling. Operator comfort is not a concern in most export markets. It is becoming a greater concern in North America as working conditions become a factor in labour negotiations. Nonetheless, only one Bombardier customer has ever asked for factory-installed air conditioning. This could change in future if locomotive cab air conditioning could be made more cost-effective and reliable.

23. In general, climatic testing or design for climatic conditions is not yet a major activity in locomotive design and development. Evolutionary nature of railway standards development is a major reason for previous lack of interest. Concern for climatic performance is becoming most important, however, and testing may become a more common practice if facilities are available and if the trend to demand climatic testing in operator-purchase specifications continues. Several U.S. railroads are using specifications prepared by consultants which demand some form of controlled climatic testing. At present, requirements can be met by building a temporary 'tent' and injecting hot or cold air.

24. Many of the areas for further locomotive development would benefit from controlled climate testing which included simulation of moving air. Mr. Bergner was cautiously enthusiastic about the possibilities of performing better tests to locate air inlets and outlets on the locomotive.

25. Mr. Bergner and Mr. Clarke suggested the following additional contacts or industries as potential users of a facility:

- UTDC
- Vickers
- Fruehauf

DEPARTMENT OF NATIONAL DEFENCE
LAND ENGINEERING TEST ESTABLISHMENT (LETE)

August 19, 1981

Major Ken Lee
O.C. M Squadron
101 Colonel By Drive
Ottawa, Ontario
K1A OK2

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1. Since Maj. Lee is a member of the study steering committee, discussion proceeded directly to an evaluation of LETE's test facility needs.

2. LETE is the organization which performs testing of land-based military equipment. Most of its work is mission-oriented work with an emphasis on compliance testing and problem solving. LETE does not perform basic R&D and seldom does standards development.

3. LETE has relied heavily on NRC for its past testing programs and generally finds that the Ottawa location of NRC allows for easy access and simple logistics. Maj. Lee suggested that a distant location (e.g. Toronto) which required obtaining accommodation for test personnel would be extremely costly and awkward.

4. LETE testing has been largely concentrated on land vehicle testing. Cold starting, performance tests, icing studies, rain simulation and simulation of road load are all desirable test capabilities. In addition temperatures of $-40^{o}C$ to $+40^{o}C$ would cover the necessary range of test condition.

5. Maj. Lee indicated that LETE would be very interested in testing vehicles under airflow simulation, especially if a dynamometer were present. Air speeds need not be great since most vehicles would not exceed 65 km/h. The dynamometer would have to accommodate at least a 4-wheel-drive vehicle and perhaps even tracked vehicles. Nonetheless, Maj. Lee indicated that there were many tests which do not require a dynamic facility and that the capability, while desirable, was not essential.

6. Maj. Lee felt that the proposed NRC Uplands climate chamber would fulfill all of LETE's essential testing needs.

7. Comments on specific tests at LETE include the following:

   a) Leopard Tank:

      - 41-45 tonne gross vehicle weight is too heavy for existing NRC facility

      - Icing of vision ports and periscopes is a potential concern-might require a dynamic facility

- Heat output of Leopard is approx. 400 kW for cold start procedure. Existing NRC can't quite get to -40°C with this load.

- Rated power of 625 kW would tax refrigeration capability if tank were run at full power.

b) Land Vehicles:

- Land vehicles produce between 190-225 kW for largest trucks

- All vehicles are 4-wheel-drive and many have dual rear axles. Dynamometer design would be difficult.

- Tests are often performed on vehicles to determine effectiveness of modifications or to respond to a spate of "unsatisfactory condition reports". There is often a degree of urgency to the tests.

8. LETE is presently considering construction of an ambient temperature test facility. This facility will be relatively modest, but will include a dynamometer.

9. LETE uses civilian test contractors to perform tests where appropriate. Maj. Lee indicated that LETE would prefer to have tests performed in a government facility (for security reasons) if at all possible.

10. Expected facility usage is approx. 40 days/year for a facility equal to or better than the proposed NRC facility. Past usage has averaged 20 days/year.

11. Possible contacts

a) Air Force - Dir. Aerospace Support Engineering
Maint. Policy, Techniques & Tasking
Maj. R. R. Simpson 993-2838
Rockliffe

b) Coast Guard/Maritime - Dir. Maritime Engineering Support
Lt. Col. G. Blackwell
966-3157

c) General Motors (Military Vehicles)

d) Bombardier Armed Vehicles, Military Sales Division

NATIONAL RESEARCH COUNCIL OF CANADA

A3-10

OR8

August 18, 1981

Mr. T.R. Ringer
Manager
Low Temperature Laboratory
Montreal Road Campus
Ottawa, Ontario

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1. Mr. Ringer is the manager of NRC's Low Temperature Laboratory (LTL) and is widely acknowledged as the leading Canadian expert in low temperature testing. This meeting was also attended by Mr. C.A.M. Smith, Manager of NRC's Railway Laboratory. The LTL is located on the NRC Montreal Road campus.

2. Facilities at the LTL consist of:

   a) Static Cold Chamber - 15.5m (L) by 4.5m (H) by 3.6m (door width); minimum temperature -60°C; freezing rain and graupel-type snow simulation; low-speed wind simulation

   b) Low-Speed Icing Tunnel - 1.37m square test section; minimum temperature -30°C; maximum velocity 290 km/h; freezing rain capability

   c) High-Speed Icing Tunnel - 0.3m square test section; minimum temperature -40°C; maximum velocity Mach 0.9; low-speed plug available

   d) Outdoor Snow Ingestion Facility- complete meteorological instrumentation; ice and snow ingestion tests for jet turbine engines, HVAC systems, locomotive traction motors; natural snow used

   e) Western Laboratory (Vancouver)- small static cold chamber; 7.3m (L) by 3.6m (W) by 3m (H); minimum temperature -40°C.

3. The existing Cold Chamber is 30 years old. Approval for a large, new facility has been given by Treasury Board and tenders for design will be sent out this September. Discussions have already been held with an architect/engineer. Features of the new facility will be:

   - location at the NRC Railway Laboratory site in Uplands
   - test section overall dimensions of 30.5m (L) by 6.1m (W) by 6.1m (H)
   - capability for splitting test section into 15.2m, 9.1m, and 6.1m length sections (or combinations thereof), with independent temperature controls
   - 2 refrigerator plant rooms designed for fully automatic, unmanned operation
   - temperature capabilities of -50°C to +50°C (perhaps +55°C)
   - low-speed air circulation in conjunction with 10 overhead evaporators

DSMA International Inc.

- heavy, concrete-slab floor with railroad tracks built in; capable of handling a 272 tonne locomotive
- spur line access from mainline railway
- capability for a later, 2nd-floor addition
- estimated cost $2 million, estimated completion date April 1983
- no dynamic capability planned, although portable fans will be available

4. The location of the new facility, to be named the NRC Climatic Engineering Facility, was chosen in lieu of an 18-month shutdown of test activities had it been built on the site of the old cold chamber. Based on an 8-hour test day, Ringer thinks a comparable facility would only enjoy 30% utilization unless backed up by a strong research program.

5. In characterizing NRC's climatic testing activities, Ringer said that although some of the work is initiated internally, most results from external requests. Whether or not a test program will develop into a long-term investigation is hard to predict. NRC's chief client groups are categorized as civilian or military. He described almost all their work as "mission-oriented applied research".

6. In discussing modal splits for NRC's climatic test work, Ringer suggested that 60% is R&D, while the remaining 40% is performance testing. Of the former, 20% is devoted to the development of performance standards, 10% is testing for compliance with standards, and 5-10% is devoted to product development. Ringer felt that very little of their work could be categorized as basic research.

7. NRC-LTL's work in standards development often begins as a test requirement, turns into an R&D program, then sometimes reverts back to a test project. Ringer foresees this type of work as staying essentially continuous and constant at 20% of their total effort. Much of it involves long-term investigation. Examples are:

   - development for Transport Canada of performance standards and related testing procedures for car windshield defrosters (a long-term project being done by NRC because Transport Canada's Blainville test centre is not ready to undertake the work yet)
   - development of air brake cylinder lubrication standards for the American Association of Railways (a multi-year project)
   - development of air-borne snow concentration/visibility criteria for helicopter engine flameout testing (10 year project)
   - development for the North American railway operators' community of unofficial performance standards for track switch operation in snow conditions
   - development of a set of performance standards for moisture-induced fade in railway vehicle brake systems (a 10-year project)

8. NRC-LTL's work in product development arises from a relatively recent Council-wide Programme For Industry/Laboratory Projects (PILP). PILP involves a transfer of technology from NRC to private industry, with

an emphasis on development work rather than research. NRC-LTL have completed two such projects in the last five years, the major one involving an icing detector for helicopters. NRC lent assistance to the industrial firm developing the unit throughout the research, development, pre-production and qualification testing phases.

9. Ringer discussed at length the climatic simulation requirements he is familiar with for a range of test clients. These included temperature ranges, freezing rain, snow, cloud icing, wind velocities, etc.

10. Regarding low temperature extremes, Ringer gave the following values for various test clients:

    * -65°C: army (U.S.), air force, some electrical switchgear (rarely)- Reference US MIL Spec. 5272
    * -50°C: army (Cdn, usually), civilian transportation equipment (occasionally)
    * -40°C: army (Cdn, occasionally), civilian transportation equipment (usually), electrical switchgear (usually)
    * 0° C: naval, marine

    Ringer also noted that for Canada, for the month of January, statistics show that less than 1% of the land area sees -50°C for 1% of the month.

11. For high temperature extremes, Ringer gave +55°C as the usual upper limit. Exceptions requiring higher temperatures are high-speed aeronautical tests, some military ground equipment and some civilian equipment (subjected to solar heating).

12. For freezing rain studies, NEMA and SEMA require compliance testing for the performance of electrical switchgear. Test requirements dictate both the amount and direction of the freezing rain relative to the test item (ie. 6.4 mm of freezing rain directed on a 25.4 mm diameter test bar at a 45° angle for a period of 1 hour). Present NRC-LTL testing has accommodated switchgear of up to 375 kva capacity, but they would like to handle 750 kva.

13. On the subject of snow simulation, Ringer said that there are no specifications for tests involving snow. NRC are the only Canadian organization carrying out this type of simulation testing. Snow can only be simulated in graupel form (not the usual dendritic), in much the same fashion as artificial snow made by ski resorts. Crystal size is somewhat controllable, but the usual control parameter is accumulation (ie. equivalent inches of snowfall per hour).

14. Cloud icing simulation, used for aero, marine and structural icing studies, has been refined to quite exacting test standards (droplet sizes of 15-40 microns, liquid water content of 0-2 gm/m^3). Some wind velocity is usually specified, but values are very low. Aero icing studies have been performed by NRC for an international clientele (France, England, Germany, Canada). Only the French have developed a full performance specification.

15. NRC closed down its Low-Speed Icing Tunnel in 1980 due to extremely low usage (under 100 hr. per year over the last 30 years). Ringer explained that aero icing studies are only carried out during development of new designs. Furthermore, the U.S. FAA allow for either analytical or experimental proof of icing performance and so far most manufacturers have opted for the former. Recently, non-aero users (eg. Bell Canada, Ontario Hydro, and Hydro Quebec) had become the facility's major clients. One internal NRC program (since completed) had taken up 75% of available test time. NRC have volunteered to install an icing simulation capability at their VTOL facility in lieu of the Low-Speed Icing Tunnel, but so far no one has expressed interest. Canadair and de Havilland (Challenger and Twin Otter respectively) were the major Canadian aero clients. The Canadair program has been completed. Ringer said that Canadian aero manufacturers often hired U.S. assistance for their icing studies.

16. NRC-LTL have had a lengthy but sporadic involvement with marine icing studies. The program, initially triggered by the loss of fishing trawlers due to ice-induced capsizing (about 2 per year, internationally, on average), was suspended this year due to minimal Canadian interest. There was a proposal 10 years ago for a new NRC facility to specifically address the problem, but funding was never granted. Ship-icing studies are complicated by the need to use salt water and by the impossibility of using scale factors. The formation mechanisms are very complex and the potential remedies diverse. Germany, Russia, England, Japan and Alaska have all done studies in this area.

17. NRC have only used external facilities once for climatic testing, and the facility (British) proved inadequate.

18. Ringer does not believe that a dynamic CCTF in Canada will have much impact on performance specifications development work by NRC. He cites the lack of comparable facilities worldwide, noting that even if standards were developed there would be nowhere except that facility to carry out compliance tests.

19. Ringer feels that the majority of U.S. railroad operations occur in climates which do not impose low temperature conditions on equipment.

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APPENDIX IV

NRC CLIMATIC ENGINEERING FACILITY

(BUILDING U-88)

TECHNICAL DOCUMENTATION

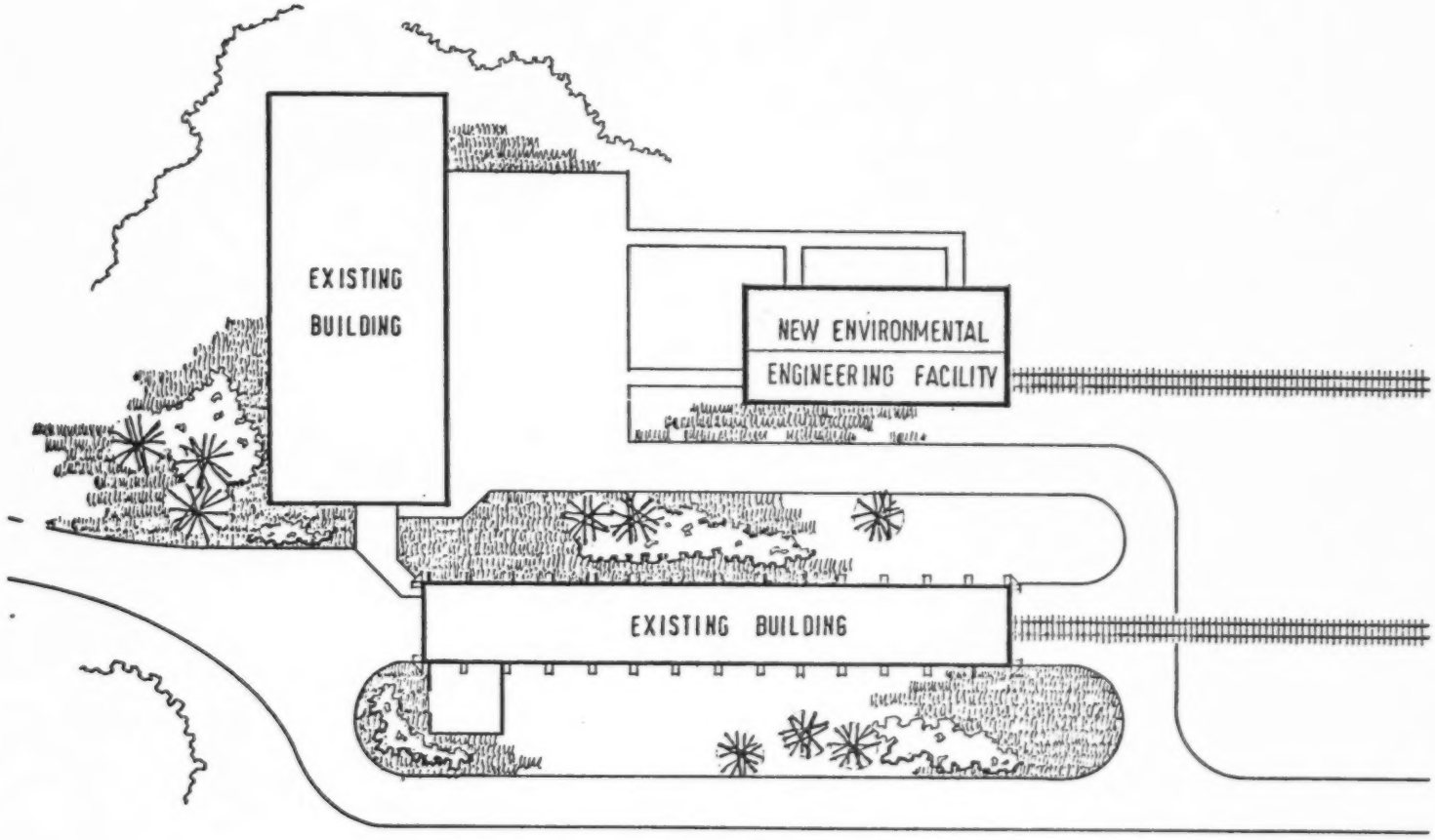

Figure AIV-1 NRC Climatic Engineering Facility Plot Plan

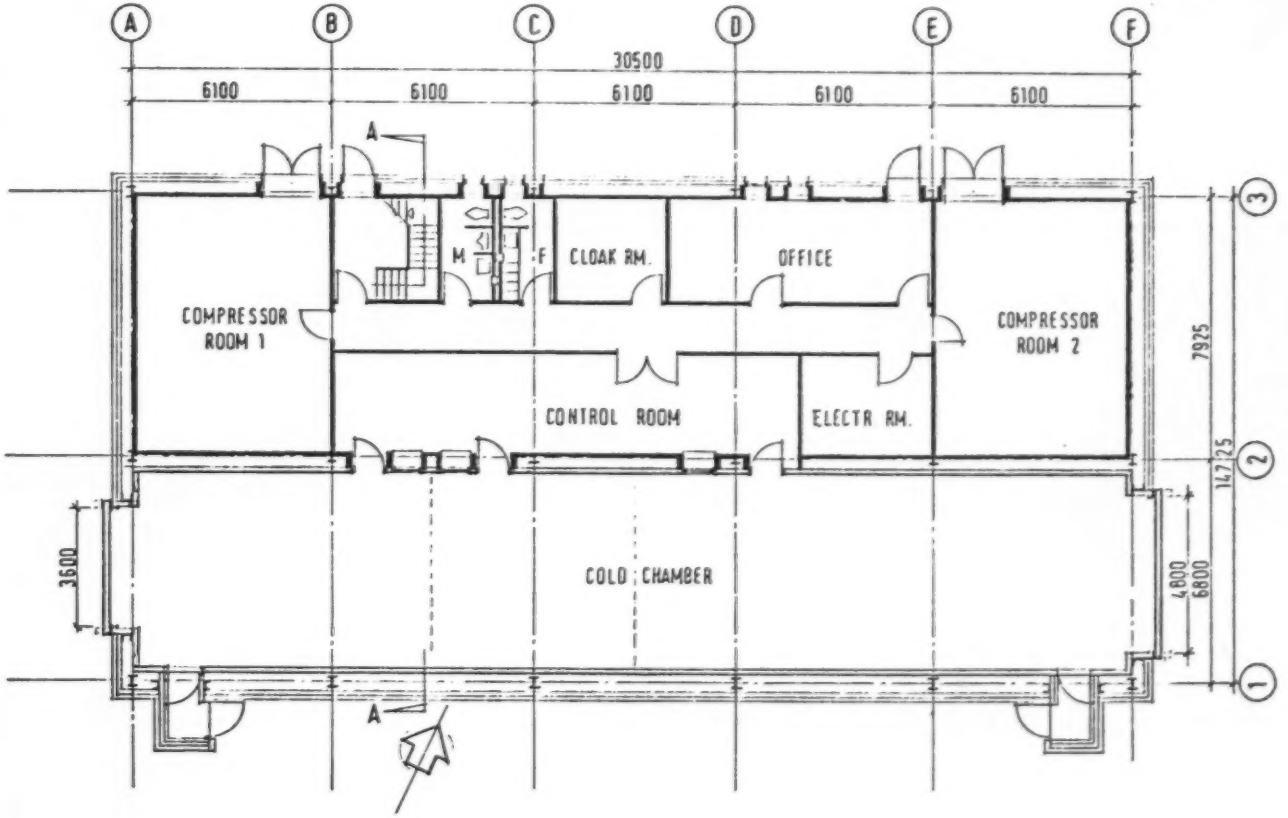

Figure AIV-2 NRC Climatic Engineering Facility Ground Floor Plan

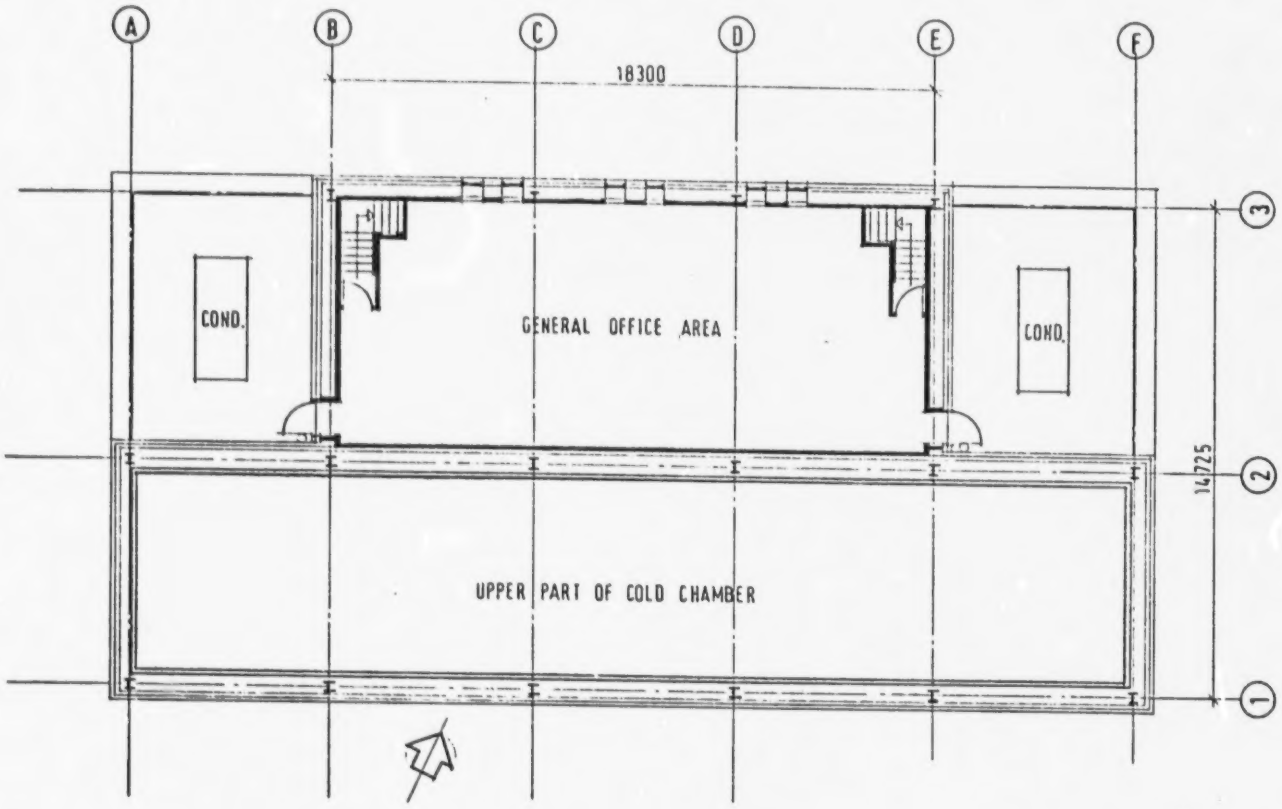

Figure AIV-3 NRC Climatic Engineering Facility Future Second Floor Plan

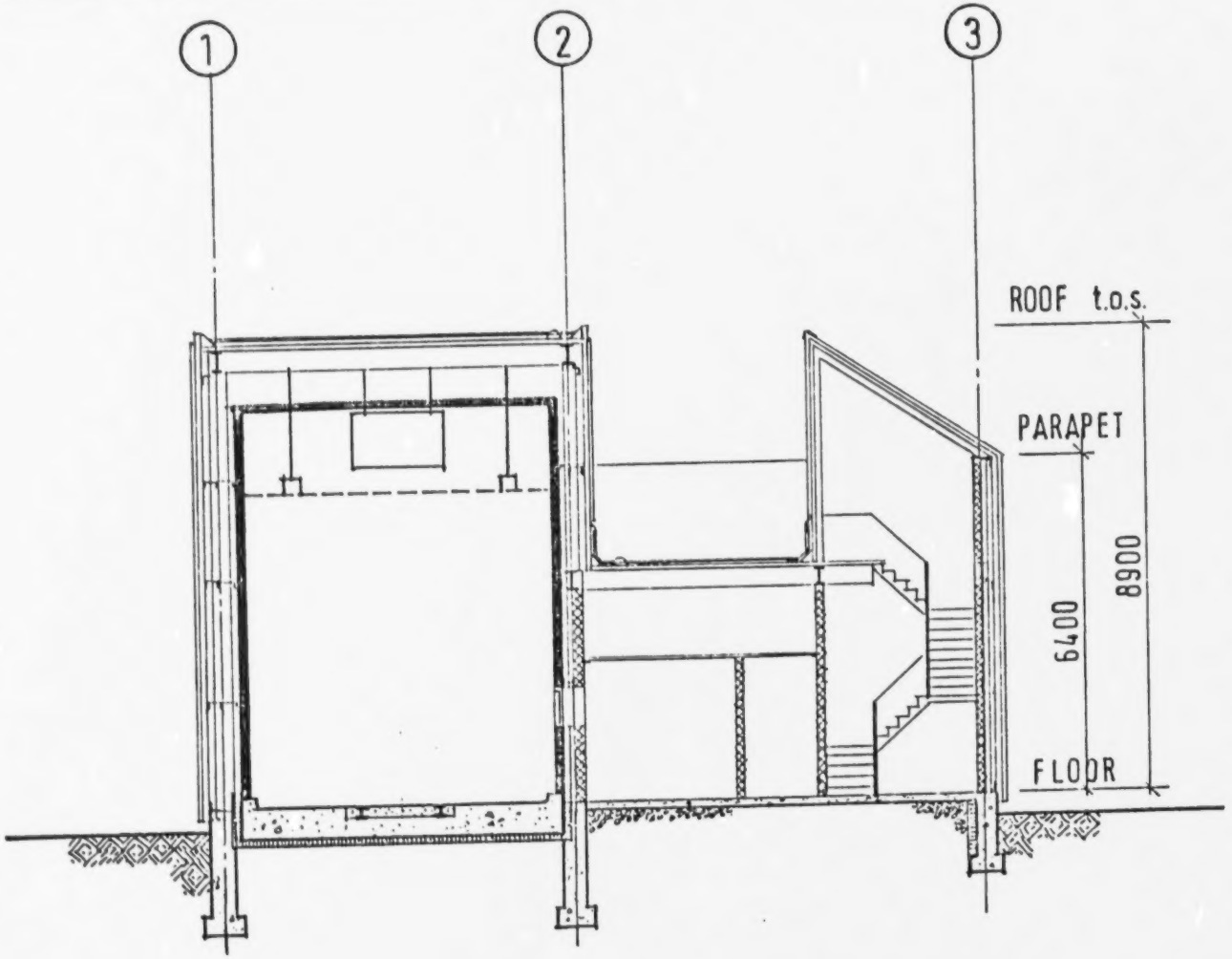

Figure AIV-4 NRC Climatic Engineering Facility Cross Section

POOR

QUALITY

ORIGINAL